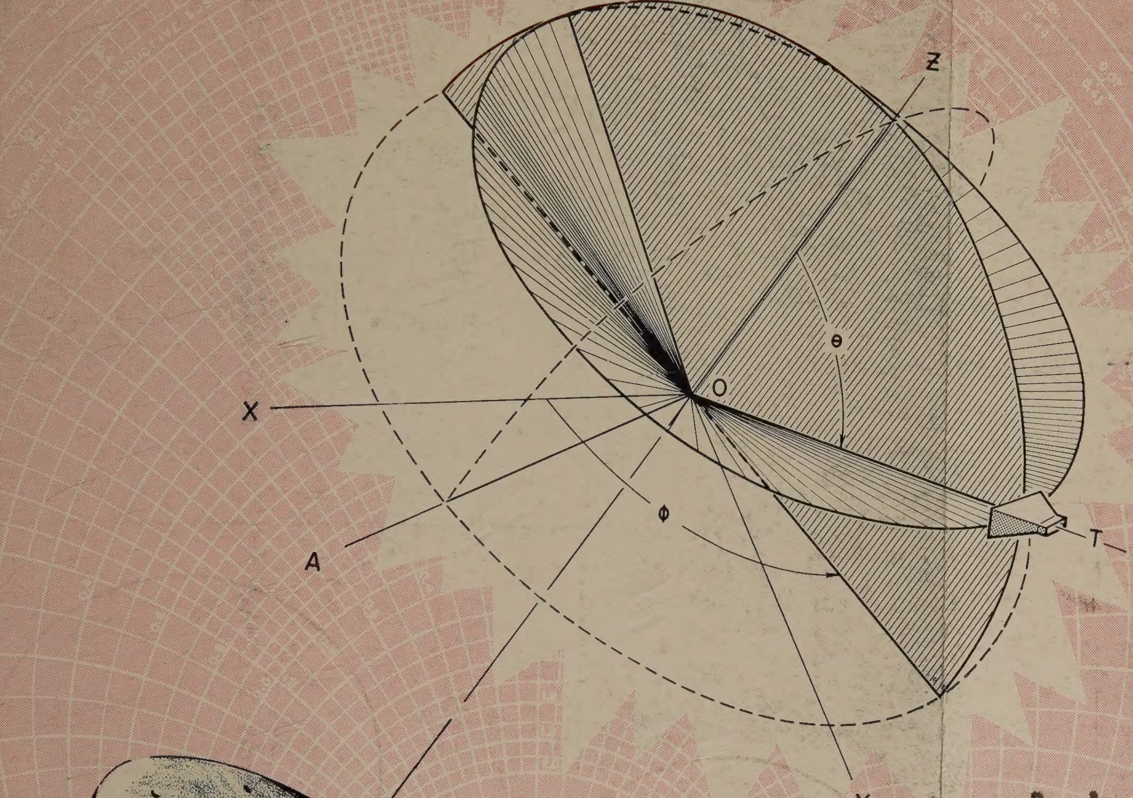
ARCH 1960
LUME 3 • NUMBER 3

- Button — Historical Sketch of Ferrites and their Microwave Applications
- Hogg and Mumford — The Effective Noise Temperature of the Sky
- Hollis — Antenna Measurements - Part II
- Steere — Novel Applications of the Smith Chart

e microwave journal



Dr. Bernerd Herzog,
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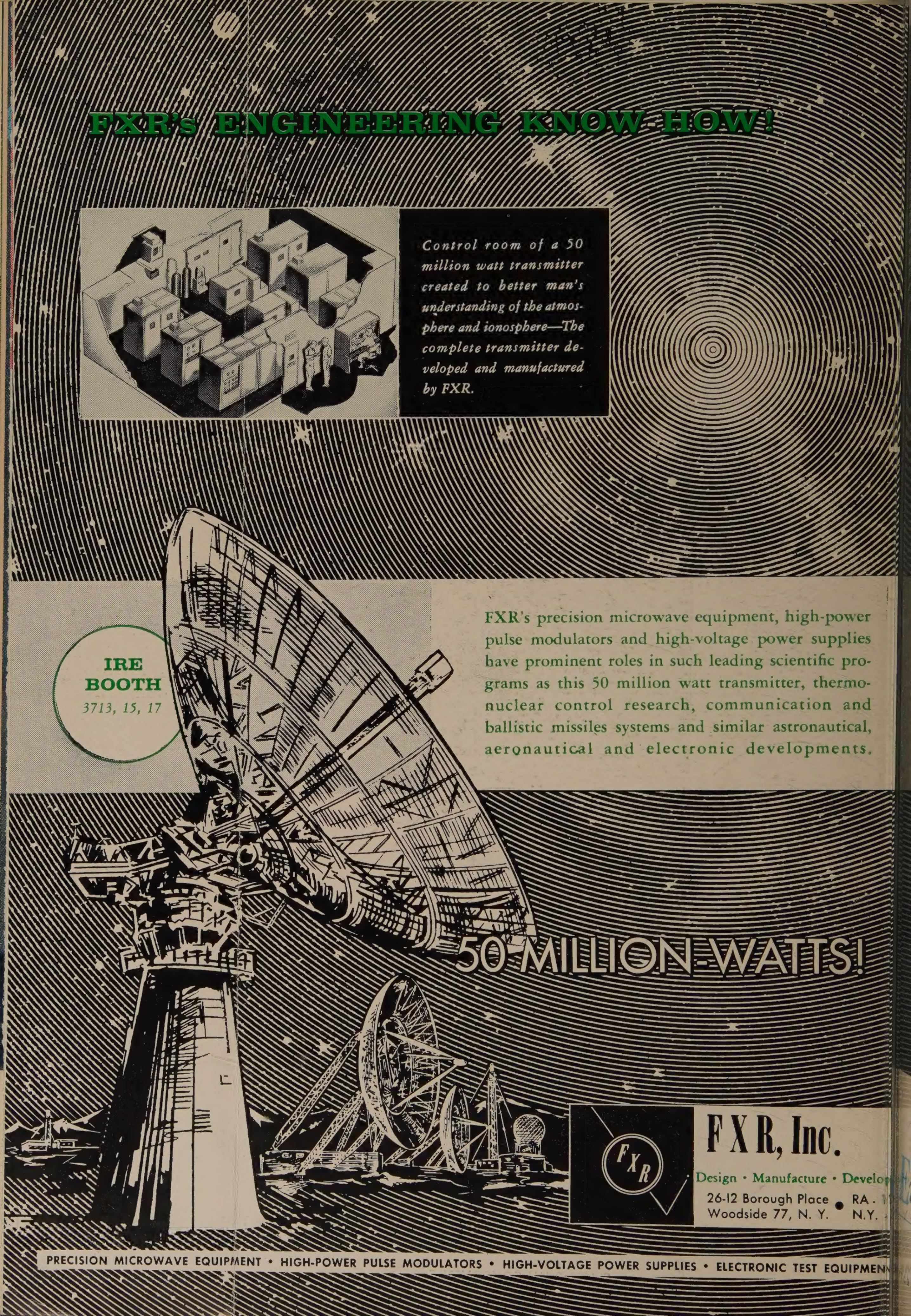
1960 INTERNATIONAL IRE CONVENTION ISSUE



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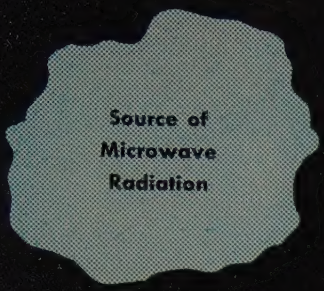
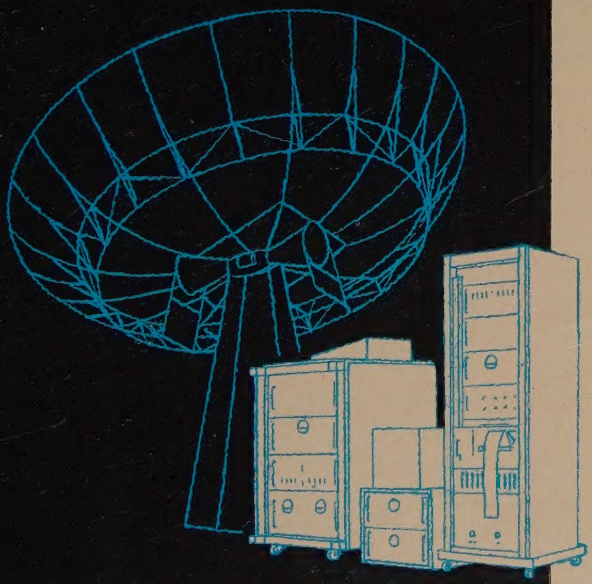


What is a Microwave Radiometer?



The fundamental ingredients of any microwave radiometer consist of an antenna, an amplifier, a detector, and an indicator. From a thermodynamic standpoint the antenna may be considered as a device which transports its radiation resistance at the input terminals of the receiver into a thermal reservoir contained within the volume of space "observed" by the antenna and determined by its directive characteristics. If we then assume that the observed medium is a composite black body reservoir at some temperature T, then the temperature of the radiation resistance of the antenna will come into equilibrium with the temperature of this reservoir. The amplifier portion of the receiver then amplifies the power presented to its input terminals by the radiation resistance. This power level is the well known Johnson noise power KTB where K is Boltzmann's constant, T is the equivalent temperature of the radiation resistance and B the predetection bandwidth of the amplifying device. The power input to the amplifier is then equivalent to the power output of a resistor matched to the receiver input, and immersed in a thermal reservoir at temperature T. Since this power level is directly proportional to the temperature of the reservoir, the signal input can be expressed in temperature units (of degrees Kelvin).

In the Rayleigh-Jeans approximation for the brightness of Planck radiation, the brightness per unit cycle is inversely proportional to the square of the wavelength, whereas Johnson noise power is independent of frequency and dependent only upon temperature. The thermodynamic balance of the two sources of power is obtained, in a receiving system, through the wavelength characteristic of the average antenna cross section. When performing the integration of the product of brightness per unit wavelength and antenna cross section, over the bandwidth of the receiver and the solid angle of the antenna aperture, the wavelength-dependent terms cancel. Hence an antenna totally "immersed" in a black body at temperature T will contribute a constant power output at its terminals, independent of frequency.

In summary, the logic is as follows: The power incident upon the antenna aperture within the bandwidth of the receiving system produces a thermal bath for the radiation resistance of the antenna, at the temperature of the "composite equivalent" black body viewed by the antenna. This antenna temperature is then transmitted to the amplifier via the "Johnson noise mechanism," where it is amplified in the presence of the noise power attributable to the man-made circuitry.

The signal strength is recorded in temperature units (degrees Kelvin).

Ewen Knight radiometers of the HII series are capable of detecting temperature changes at the receiver input terminals as low as 0.01°K, which is approximately 10^{-25} watts/cps.

wen Knight CORPORATION

AT THE FRONTIERS OF *Electronics*

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MARCH, '60 vol. 3 - no. 3

the microwave journal

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Microwave Engineering Aspects of Electron Linear Accelerators - Part I

Microwave Radiometry - Part I

The Effect of Silver Plating on Attenuation at Microwave Frequencies

Simple Calculations of Waveguide Wavelength

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TORM

ARNING... BY RADAR

Atmospheric turbulence has the characteristic of reflecting microwave signals, with the degree of reflection depending on the severity of the turbulence. Returned to the aircraft, this reflected radar warning is displayed in a manner that warns the pilot of the exact location and extent of the turbulence, enabling him to change his course and fly around dangerous storms. Since the radar display also shows him "holes" in storms where there is little or no turbulence, the pilot can choose a course that will result in maximum safety and minimum delay.

Commercial airlines use Varian klystron-equipped weather radar to assure the comfort and safety of passengers and the reduction to a minimum of storm hazards and delays. Photo above shows radar antenna inside the Radome nose of a United Air Lines plane.

In addition to the technical advantages of Varian klystrons to the equipment designer, their rugged mechanical construction and long life are vital benefits to the user. These characteristics are reasons why Varian has become the world's largest manufacturer of klystrons.

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NEW FROM PRD NEW FROM PR

FEATURES:

- A new low in noise levels—down to 0.007 μv providing 0.02 μv full scale sensitivity at minimum bandwidth.
- 5 db steps
- Attenuation range of 85 db
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- All meter scales automatically normalized when switching ranges
- Large 5¾″ meter with 1% linearity
- Continuous gain control over 15 db range
- Continuously variable bandwidth control
- Front panel meter monitors bolometer bias current

SPECIFICATIONS:

Frequency: 1,000 cps; adjustable over a 2% range.

Sensitivity: 0.02 μv at minimum (4 cps) bandwidth. 0.1 μv at maximum (40 cps) bandwidth.

Noise Level: 5db below full scale (0.007 μv at minimum bandwidth).

Amplifier Q: 250 at 4 cps; 25 at 40 cps.

Bandwidth: Continuously variable from 4 to 40 cps.

Calibration: Square Law. Meter reads SWR, db.

Range: 85 db. Input attenuator provides 70 db in 5 db steps. Gain control provides 15 db adjustable. Accuracy ±0.1 db per 10 db. Maximum cumulative error of ±0.2 db at 40 cps bandwidth.

Scale Selector: Expanded, Regular, and Bolometer Current. Meter scales always normalized when switching from scale to scale or from expanded to regular.

Meter Scales: SWR: 1-4; SWR: 1.8-6; SWR: 3.2-10; SWR: 6-15; Expanded SWR: 1-1.3; db: 0-10; Expanded db: 0-2.3.

Input Selector: 220,000 ohms; Crystal; Bolometer. Bias provided for high 8.4 ma bolometer or 4.3 ma low current bolometer. Bias adjustable ±15%. A bolometer protective circuit permits any switching operation or cable connect-disconnect without damage to bolometer.

Output: Jack for 1500 ohm recorder, 1 ma full scale deflection.

Input Connector: BNC Jack.

Power: 115/230 v ±10%, 50-60 cps, 40 watts.

Dimensions: Cabinet: 7¾″ wide, 10½″ high, 11″ deep.

Weight: 14 lbs. net.

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TYPE 277B STANDING WAVE AMPLIFIER
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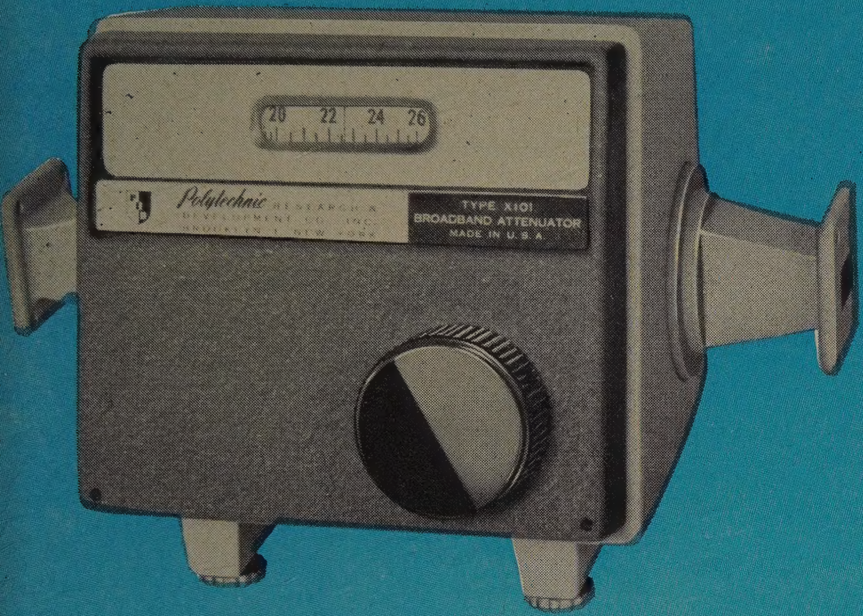
The new portable PRD 277-B Standing Wave Amplifier is designed to meet the present and future needs of microwave test laboratories. Due to its extremely low inherent noise, 0.007 μv, weak signals which once were undetectable by conventional instruments can now be measured. Attenuation in 5 db steps combined with 4 VSWR scales and a large meter permit VSWR measurements to be made with maximum resolution and accuracy.

W FROM PRD NEW FROM PRD

PRD's Brand New BROADBAND ATTENUATORS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Polytechnic RESEARCH & DEVELOPMENT CO. INC. BROOKLYN 1, NEW YORK
TYPE X101
BROADBAND ATTENUATOR
MADE IN U. S. A.

The table below indicates maximum insertion loss and dimensions.

Type No.	Freq. Range	Max. Insertion Loss	Insertion Length	Height	Depth
G 101	3.95 — 5.85	0.5 db	18⅞	6 5/16	7 3/16
C 101	5.3 — 8.2	0.5 db	14 7/16	6 5/16	7 3/16
H 101	7.05 — 10.0	0.5 db	11⅜	6 5/16	7 3/16
X 101	8.2 — 12.4	0.5 db	9	6⅛	6¼
U 101	12.4 — 18.0	0.7 db	7 11/16	5⅛	6¼
K 101	18.0 — 26.5	0.7 db	7 9/16	5⅛	6¼
A 101	26.5 — 40.0	1.0 db	6 13/16	5⅛	6¼

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FEATURES:

- Short insertion length
- Full *60 db* attenuation range
- *Minimum* insertion loss
- Compact Tape readout
- Precision accuracy

Once again, to meet the present and future needs of microwave engineers, PRD has produced a completely new concept in test equipment. Here is a *rotary vane attenuator* in a radically modern package: small, light, rugged ...and *precise*—to fill all your needs from 3.95 to 40 kmc. The 101 series of Broadband Attenuators features a precise, compact, low-backlash drive and easy-to-read tape readout. Levelling screws quickly adjust to match transmission line heights. A simple adapter is available for panel mounting.

SPECIFICATIONS:

VSWR: 1.15 maximum

Attenuation Range: 60 db

Accuracy: ±0.1 db or ±2%, whichever is greater, from 0 to 50 db; ±3% from 50 to 60 db.

To find out more about the new PRD 277B Standing Wave Amplifier and the PRD 101 Series of Broadband Attenuators contact your local PRD representative, or phone, write, or wire:

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See the PRD 277-B Standing Wave Amplifier at the I. R. E. Show— Booths 3602-3604-3606.

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MICROVIEWS

OF THE MONTH

73 ▶

HISTORICAL SKETCH OF FERRITES AND THEIR MICROWAVE APPLICATIONS

Kenneth J. Button

Principles of operation of ferrite microwave components, including their adaptation to UHF and high-power conditions, are described in terms of the basic magnetic structure and behavior of the ferrite material. Fundamental properties of ferrites and ferrite devices have been selected to demonstrate the continued application of background knowledge to the advancement of microwave technology.

80 ▶

THE EFFECTIVE NOISE TEMPERATURE OF THE SKY

D. C. Hogg and W. W. Mumford

Sources that contribute to the effective noise temperature of a receiving antenna are discussed. Simple formulae for the noise from our galaxy are compared with experimental data. Calculated curves of antenna temperature due to absorption by oxygen and water vapor in the atmosphere are presented and compared with available measurements.

85 ▶

ANTENNA MEASUREMENTS - Part II

J. Searcy Hollis

Part II of this paper presents a description of equipment and a review of basic antenna measurements. A bibliography, a selection of commonly used antenna equations, and two nomographs are appended.

97 ▶

NOVEL APPLICATIONS OF THE SMITH CHART

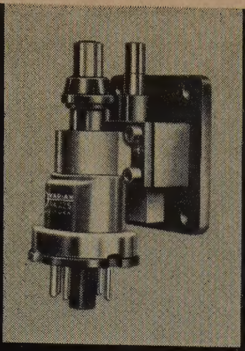
Richard M. Steere

The Smith Chart may be used in plotting variation of functions other than those dealing with energy propagation, and proves quite useful in other ways not connected with transmission lines.

OUR COVER

This month's cover graphically depicts the spherical geometry normally associated with antenna patterns. A two-axis positioner with azimuth over elevation motions permits either θ (vertical) or (conical) cuts. See page 85.

the microwave journal



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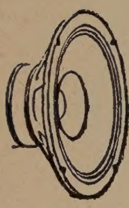

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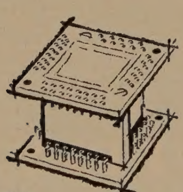
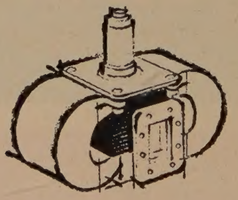


MEMORY SYSTEM
New microstack unit for coincident current memory systems saves 90% of space required by conventional stack, yet is more reliable.



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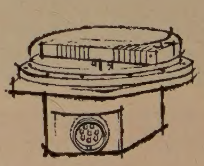
Powerful Hyflux ALNICO V magnets improve performance in many types of microwave equipment.



AUTOMATIC DIRECTION FINDER
Ferramic "E" magnetic core material helped engineers create a new concept in aircraft antenna design.

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Bring your problems involving microwave tubes
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PPM FOCUSING
NEW SPERRY STL-222
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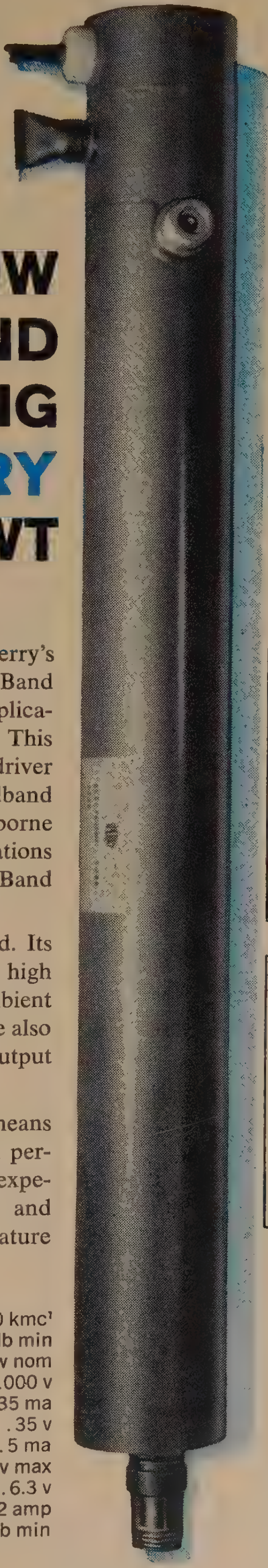


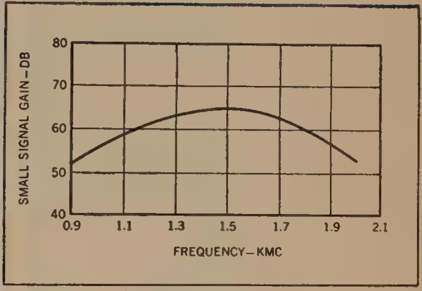
. . . cuts Space, Weight, Cost, Power Requirements — Sperry's new STL-222 provides twice the gain of ordinary L-Band tubes—actually takes the place of two tubes in most applications — yet is only 20″ long, weighs only 8.5 pounds. This important advantage suits this new CW amplifier and driver perfectly to airborne applications. Its excellent broadband stability recommends it for ground support and airborne radar equipment . . . communications . . . drone applications . . . noise generators . . . switching devices and other L-Band uses.

The STL-222 is periodic permanent magnet focused. Its tough metal and ceramic construction provides for high environmental capability, stable operation at high ambient temperatures and under extremes of vibration. This tube also features a high-mu modulating grid and high input-to-output isolation. It is short circuit stable.

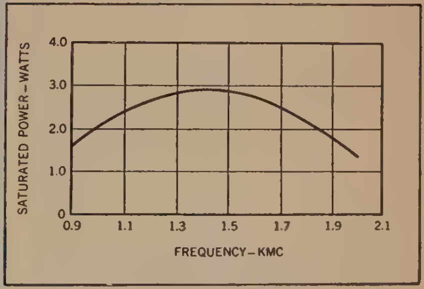
The STL-222 is now in production at Sperry, which means lower unit cost and fast delivery schedules. Advanced performance and dependability result from Sperry's long experience in klystron and TWT research, development and production. Write for complete data, outlining the nature of your application.

Specifications

Frequency Range	1.0 to 2.0 kmc
Small-signal gain	48 db min
Saturated Power Output	2 w nom
Beam Voltage	1000 v
Beam Current	35 ma
Grid Bias	35 v
Grid Current	5 ma
Grid Cut-off Signal	−20 v max
Heater Voltage	6.3 v
Heater Current	3.2 amp
Input-Output Isolation	75 db min



Small-Signal Gain vs. Frequency



Saturated Power vs. Frequency

SPERRY

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A GOLDEN OPPORTUNITY

Every March for the last several years I have attended the National IRE Convention in New York. Many of my associates have expressed disappointment in the Convention and have purposely avoided it. It is their contention that it is now too big, too commercial, too noisy, and lacking in technical stature.

The convention is big, it is commercial, it is noisy, and it does not have the technical stature that the Professional Group Symposiums have, but that is not the fault of the convention, but rather a fact of life in the electronics industry.

Like so many other things that perform a valuable function, it is certainly open to criticism. But to miss a convention is in my opinion to miss a golden opportunity nowhere else available to the working engineer.

Each year the Convention draws hundreds of manufacturers and thousands of engineers to New York City for the main purpose of exchanging information. For four days and more, engineers can pick brains, study new products, hear technical papers, and socialize.

It is a time to meet old friends and make new ones. It is a time to complain about late deliveries and apologize for same. It is a time to sell and a time to buy. It is a time to talk to competitors and to customers. It is a time to boast of your own ingenious product and to admire a competitors' fortunate design.

It is a time for quick lunches and leisurely dinners, committee meetings and sales meetings.

It is a time to measure the pace of the industry and did we keep step? It is a time to look for a new situation or to pirate your competitors' help. It is a time to worm out secrets while divulging no useful information.

It is a time to listen to technical papers and find out what others are doing.

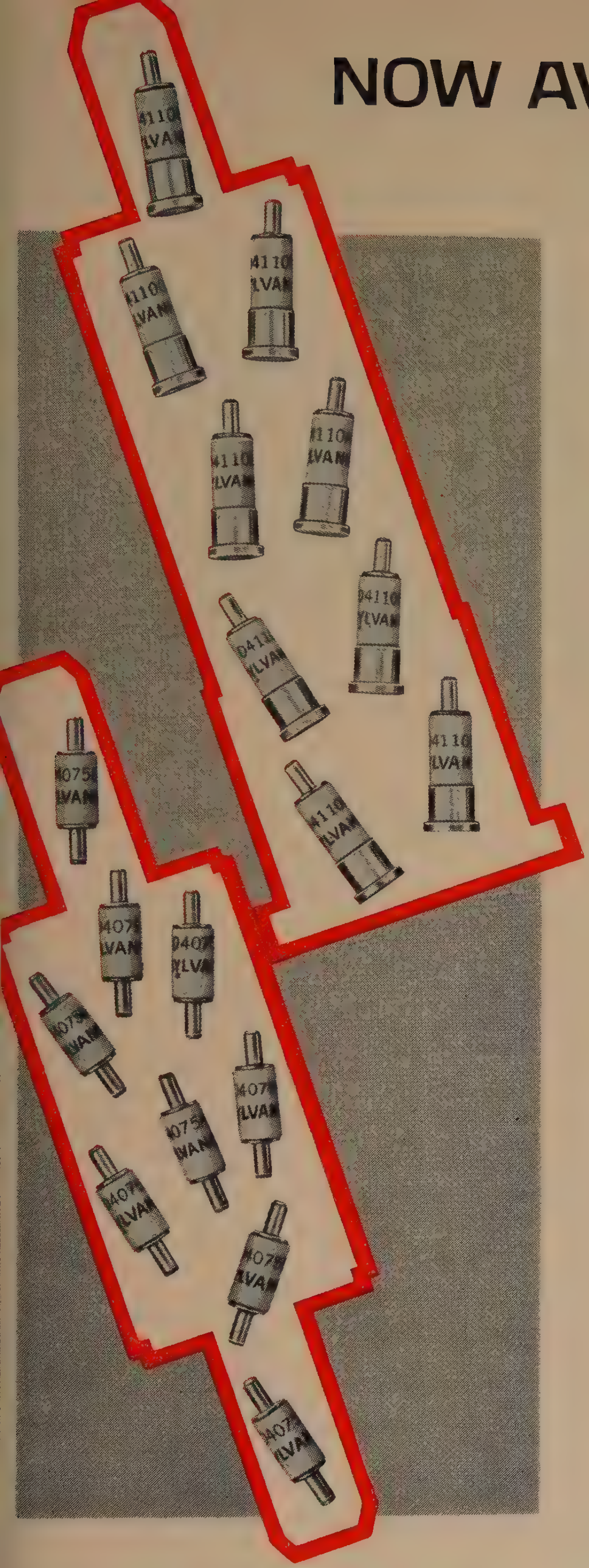
It is a time for exhaustion and excitement for the weary exhibitors.

Above all, it is a time to exchange ideas, to talk with the experts to find out what is new.

The IRE Convention is after all technical, economic, and social. To consider one as divorced from the others is a misrepresentation of the facts.

It is, above all, a golden opportunity. Don't miss it!

Ted Saad



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SYLVANIA VARACTORS—diodes that can amplify—feature cutoff frequencies as high as 100,000 Mcs!

SYLVANIA VARACTORS make practicable the design and manufacture of extremely compact low-noise parametric amplifiers, harmonic generators, up-converters, and sideband modulators.

Gains up to 40db and noise figures as low as 1.5db are achieved in many applications. SYLVANIA VARACTORS feature exceptional ability to withstand environmental conditions. Tests include temperature cycling from –65° to +150°C. High efficiency as microwave-frequency amplifiers and high gain as up-converters result from the extremely low series-resistance and extremely low series-capacitance of SYLVANIA VARACTORS.

SYLVANIA DOUBLE-ENDED TYPE	SYLVANIA SINGLE-ENDED TYPE	CUTOFF FREQUENCY† (KMc min.)	JUNCTION CAPACITANCE‡ $\mu\mu f$ max.	Q‡‡
D4075	D4110	20	4.5	1.0
D4075A	D4110A	30	3.0	2.0
D4075B	D4110B	40	2.0	3.0
D4075C	D4110C	50	1.8	4.0
D4075D	D4110D	60	1.4	5.0
D4075E	D4110E	70	1.0	6.0
D4075F	D4110F	80	1.0	7.0
D4075G	D4110G	90	1.0	8.0
D4075H	D4110H	100	1.0	9.0

Breakdown voltages are –6 volts min. at $I_R=200\ \mu a$.
†Calculated from f_{co}=(Q at 10 kmc and measured at BV) X 10 kmc.
‡Net junction capacitance measured at f=100 kc, $V_R=-6V$.
‡‡Measurement frequency=10 kmc, $V_R=-6V$.

Sylvania Varactors are available in both single-ended and double-ended cartridge packages. For further information contact the Sylvania Field Office nearest you. For technical data, write SYLVANIA SEMICONDUCTOR DIVISION, DEPT. 35-3, WOBURN, MASS.

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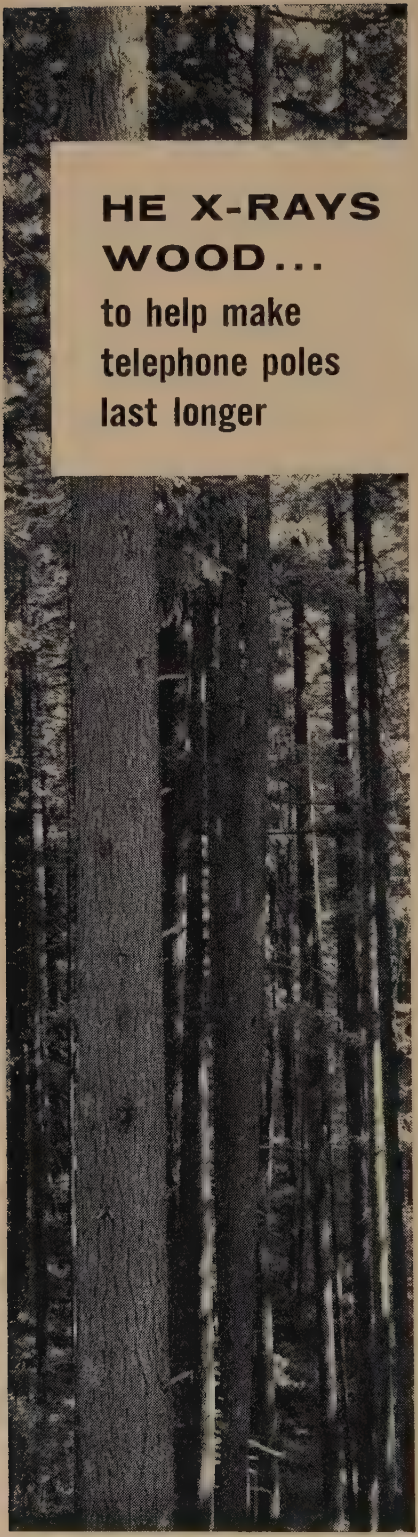

HE X-RAYS WOOD...

to help make telephone poles last longer

Chemist Jack Wright developed the use of this X-ray fluorescence machine for testing the concentration of preservatives in wood. Here he bombards a boring from a test telephone pole with X-rays.

This Bell Labs chemist is using a fast, new technique for measuring the concentration of fungus-killing preservative in telephone poles.

A boring from a test pole is bombarded with X-rays. The preservative—pentachlorophenol—converts some of the incoming X-rays to new ones of different and characteristic wave length. A radiation counter registers the intensity of these new rays. The intensity in turn reveals the concentration of preservative.

Bell Laboratories chemists must test thousands of wood specimens annually in their research to make telephone poles last longer. Seeking a faster test, they explored the possibility of X-ray fluorescence—a technique developed originally for metallurgy. For the first time, this technique was applied to wood. Result: A wood specimen check in just two minutes—at least 15 times faster than before possible with the microchemical analysis.

Bell Labs scientists must remain alert to *all* ways of improving telephone service. They must create radically new technology or improve what already exists. Here, they devised a way to speed research in one of telephony's oldest arts—that of wood preservation.

Nature still grows the best telephone poles. There are over 21 million wooden poles in the Bell System. They require no painting, scraping or cleaning; can be nailed, drilled, cut, sawed and climbed like no other material. Scientific wood preservation cuts telephone costs, conserves valuable timber acres.

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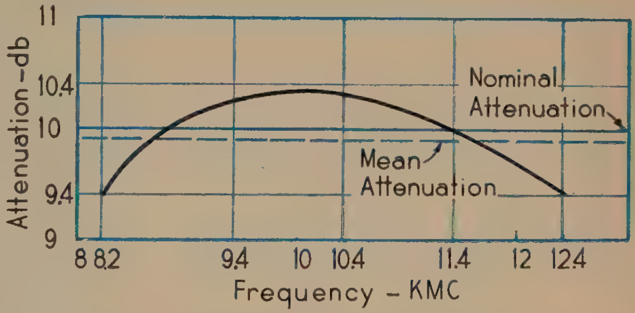
Since there are no protrusions into the waveguide, SWR's are permanent and extremely low —1.05 to 1.

ⓗⓟ 372 series attenuators are offered in six waveguide sizes, with nominal attenuations of 10 or 20 db.



Typical attenuation characteristics ⓗⓟ X372C, 10 db model.

SPECIFICATIONS

Model	Freq. (KMC)	Nominal Attenuation	Fits Waveguide Size (in.)	Power (watts ave.)	Price
S372C	2.6 - 3.95	10	3 x 1½	2	$375.00
S372D	2.6 - 3.95	20	3 x 1½	2	375.00
G372C	3.95 - 5.85	10	2 x 1	2	250.00
G372D	3.95 - 5.85	20	2 x 1	2	250.00
J372C	5.85 - 8.2	10	1½ x ¾	1	140.00
J372D	5.85 - 8.2	20	1½ x ¾	1	140.00
H372C	7.05 - 10.0	10	1¼ x ⅝	1	120.00
H372D	7.05 - 10.0	20	1¼ x ⅝	1	120.00
X372C	8.2 - 12.4	10	1 x ½	1	100.00
X372D	8.2 - 12.4	20	1 x ½	1	100.00
P372C	12.4 - 18.0	10	0.702 x 0.391	1	115.00
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COOLANOL: Monsanto T. M., Reg. U. S. Pat. O'

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n their test program, Sperry engieers found that Coolanol 45 at one gpm gave *laminar flow* conditions dequate for cooling at the input powers specified—up to several kilovatts. Laminar flow also did away vith coolant noise which in previous ubes had created amplitude or frequency variations at rf outputs.

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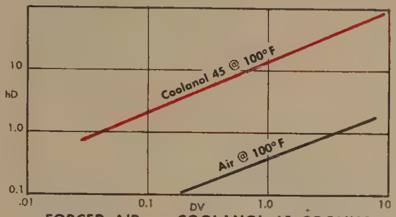
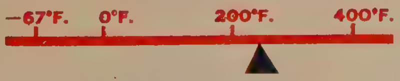


FORCED AIR vs. COOLANOL 45 COOLING
h Film Coefficient (BTU/hr/°F/ft²)
D Diameter of Channel (ft)
V - Velocity (ft/sec)

2. Liquid-phase . . . even at 400°F. The high boiling point of Coolanol 45 allows its use in operating systems to 400°F. Fluid flow past hot-spot areas can be precisely controlled with Coolanol 45 . . . without boiling which can cause pump cavitation and vapor binding. Water-glycol types or the vapor-phase coolants cease to function as pumpable liquids near the 200°F. mark. You don't need extra pressurization equipment or special pressurized lines for liquid-phase Coolanol 45.

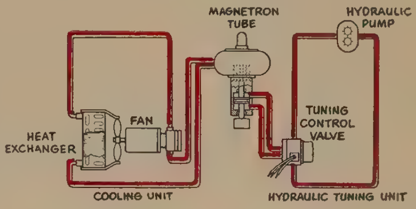
Coolanol 45—
liquid-phase operating range



Vapor-phase coolants, water types
boil near this temperature

3. One fluid for cooling and hydraulic needs. Coolanol 45 has good lubricity and makes an excellent high-temperature hydraulic fluid. It permits you to standardize on *one* fluid for both cooling and hydraulic needs—simplifies complex systems, and reduces variables.

The schematic depicts a countermeasure unit in which Coolanol 45 cools the magnetron tube and actuates the hydraulic tuning mechanism.



4. Standard materials and compatible equipment available now. Packings and seals are available in many compoundings and configurations for temperatures normally found in Coolanol 45 systems. The most widely used materials are Neoprene W, LS-53, and Buna N. Also, backup rings and hose assemblies are readily available for high-temperature use. Several manufacturers supply off-the-shelf cooling packages for Coolanol 45 systems; others will build complete cooling packages to specification. For information on complete cooling systems or component suppliers, write Monsanto.

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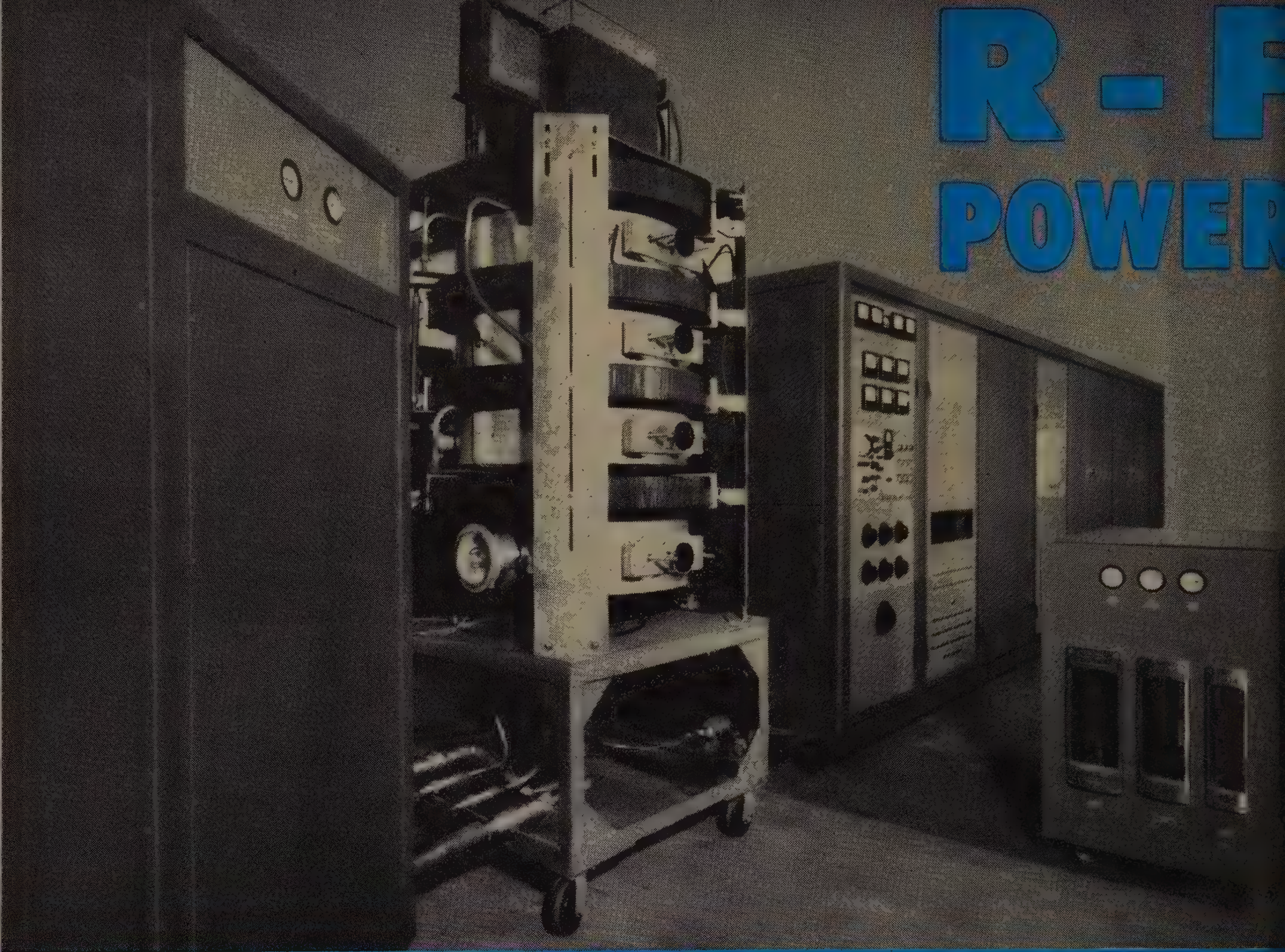

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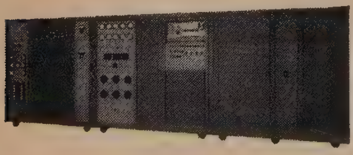
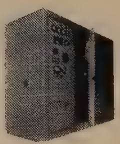
50 KW—MODEL 241T

This equipment, illustrated above, is typically capable of 50-kw c-w output with 45-db gain in the 300 to 500-mc range, using an Eimac 4KM170,000LA klystron. Pulse capability up to 200 kw can be provided.



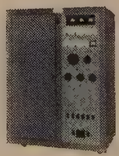
10 KW—MODEL 82T

Considering tubes readily available, this Levinthal transmitter can be supplied with typical gains ranging from 25 to 40 db in frequency bands ranging from 225 to 2400 mc.



2 KW—MODEL 208T

Here, a series of typical klystrons gives a selection operations with gains from 30 to 50 db over frequen bands including extremes of 385 and 8500 mc.



1 KW—MODEL 74T

A variety of klystrons is available to provide the Mod 74T with typical gains from 25 to 60 db and frequen bands ranging from 385 mc to 10.8 kmc.

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Levinthal specializes in the production of high-power r-f transmitters and modulators for c-w pulsed application. There are presently numerous attractive openings in the expanding engineer force at Palo Alto. If you are thinking about a new direction in your career, send us your resu and let us tell you something about the general advantages of working on the San Franci Peninsula and those applying to Levinthal in particular.

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A REAPPRAISAL OF STRIP TRANSMISSION LINE

SEYMOUR B. COHN
STANFORD RESEARCH INSTITUTE

Associate Editor
the microwave journal

THE GREAT SURGE OF INTEREST in strip transmis- n line during the early and middle 1950's was the cause, l also the result, of great expectations among micro- ve engineers. In the first flush of enthusiasm it was lely thought that strip line would rapidly replace wave- de and coaxial-line circuits for most applications. This not been the case. Waveguide and coaxial line are still ng used in most instances, while strip line has gained y a minor, though firm, position. Now that enough years e passed so that strip line can be viewed in proper spective, an attempt will be made in this editorial to luate strip line's current status and proper role in rowave design.

lthough rigid-strip conductors between parallel ground nes had already had some applications in transmission- circuits, the great potentialities of strip transmission were first brought to general attention in 1951 and 2 with publication of R. M. Barrett's papers on printed ns of construction.[5, 7] Printed-circuit techniques had ady won their place in lower-frequency applications, the possibility of using these economical mass-produc- methods in the microwave range was highly appealing. the next five years, a vast amount of research and de- pment was carried out all over the world, resulting in ood of published papers. The bibliography appended his editorial gives a healthy sampling of this literature.*

The three strip-line cross sections that have found widest acceptance are shown in Figure 1. The strip conductors in (a) and (b) may be photo etched, while the thick, rigid strip in (c) must be machined or otherwise formed and fabricated into the desired shape. In (c), support must of course be provided for the strip at frequent points. Because of dissipation loss in the dielectric material, (a) usually has the least Q (and greatest attenuation) of the three types, while (b) is intermediate, and (c) best. The superiority of (c) in this respect is further enhanced by the fact that for the same characteristic impedance a thick strip conductor has lower resistive loss than a thin strip. In addition to the effect of dielectric loss, the Q in (a) is lowered still further by the usual practice of making the plate spacing less than in (b) and (c), in order to reduce the volume and weight of the dielectric material. A further disadvantage of (a) is that the variation of thickness and dielectric constant of available copper-clad dielectric sheet stock make the phase velocity and characteristic impedance of the line somewhat unpredictable, giving a greater variation of electrical performance in production than is obtainable from (c). This is also to a lesser extent true of (b). Thus, against the production advantage and compactness of photo-etched sandwich construction, one must weigh the disadvantages of increased loss and variability. These disadvantages might in the future be reduced, however, if sheet stock with lower loss and greater uniformity could be made available to the microwave industry.

The air-dielectric strip line in Figure 1(c) is comparable in Q to air-dielectric coaxial line, when the plate spacing of the former is about seven-tenths the outer diam-

(*Continued on page 20*)

The appended bibliography is based (with permission) on given in a fine review article by A. F. Harvey published in Proceedings of the Institute of Electrical Engineers (Lon-)[35a] Additional references have been inserted by the author his editorial.

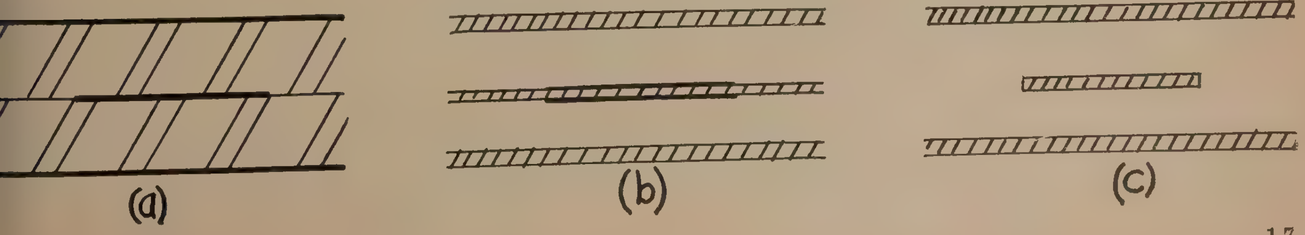
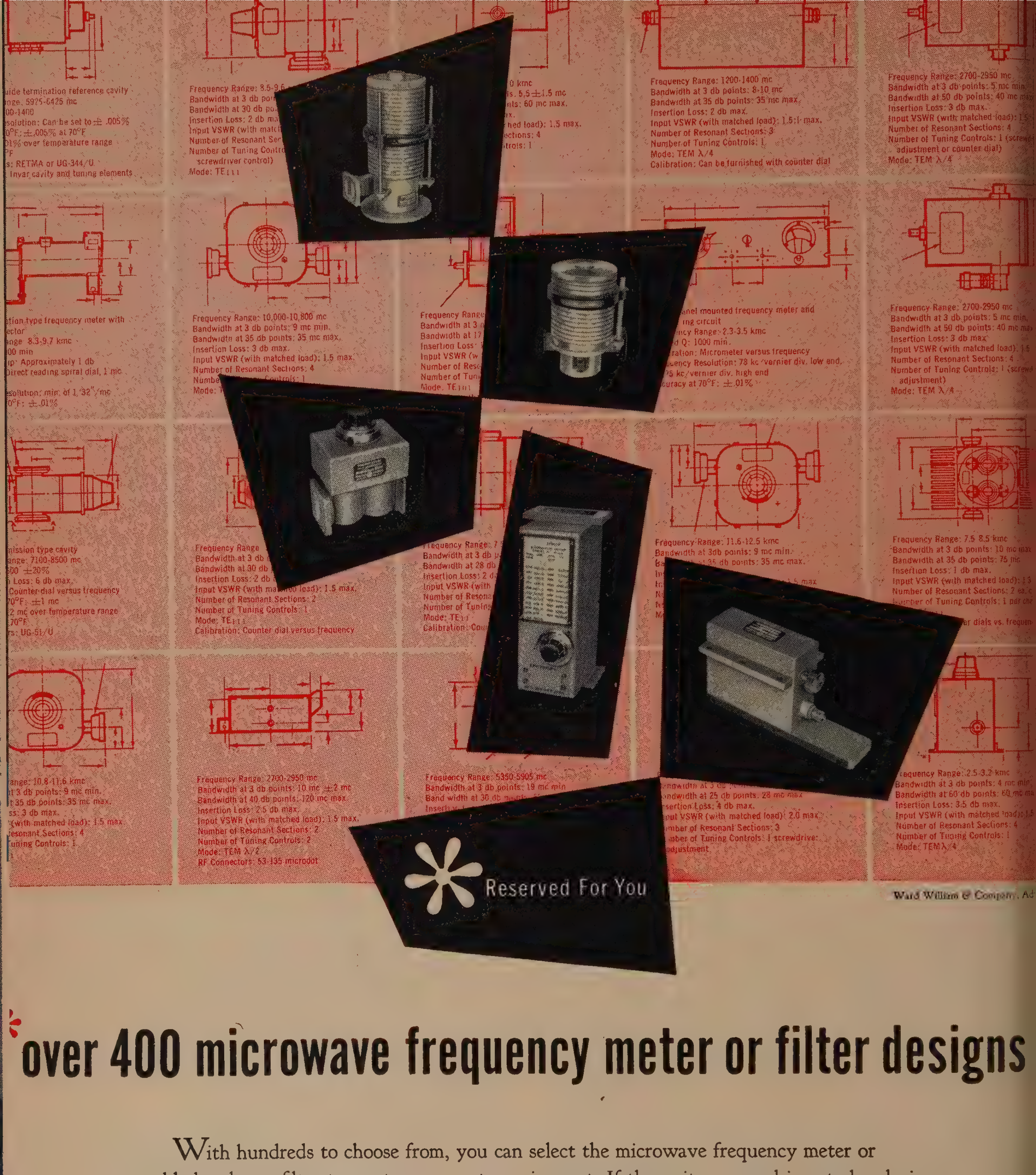


Figure 1 — Three useful forms of strip transmission line.



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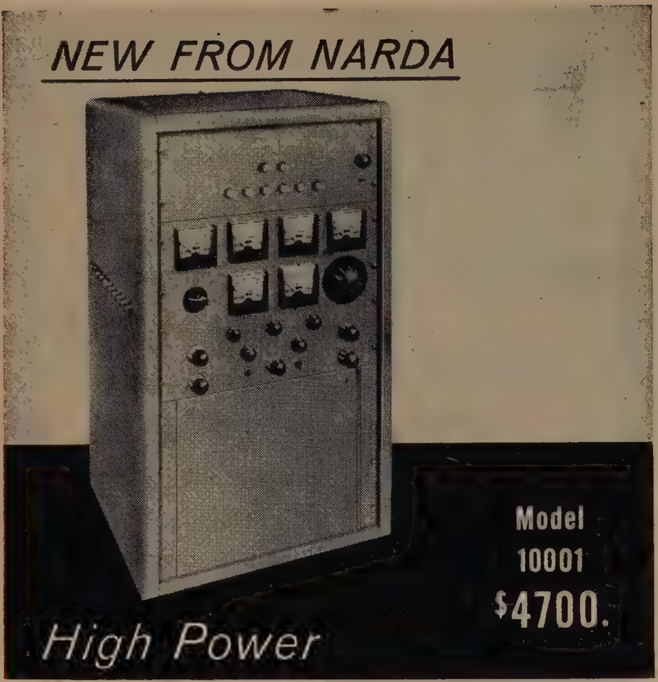

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High voltage supply: Continuously variable from 0 to 4 KV at 100 ma; **Pulse power:** 18 KV at 20 amps max.; **Magnetron filament supply:** Cont. variable from 0 to 13 volts at 3 A; **Rep. rate generator range:** Cont. variable from 180 to 3000 pps; **Pulse width:** 1 microsecond at 70% points, rise time 0.15 microseconds, max. slope 5% (other pulse widths available); **Size:** 38″ h, 22″ w, 18″ d. **Weight:** 150 lbs.

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Dr. Seymour Cohn

(*Continued from page 17*)

eter of the latter, as illustrated in Figure 2. Quality an uniformity of performance are about on a par. It is eviden in Figure 2 that although the height of a given planar ci cuit may be less with strip-line construction, the widt must be greater, with over-all cross-sectional area and vo ume of the assembly about the same. Therefore, there i no distinct advantage in either method of constructio from standpoints of performance and size. The compara tive fabrication expense must be evaluated for each appl cation, with the strip-line circuit sometimes preferabl and other times the coaxial circuit.

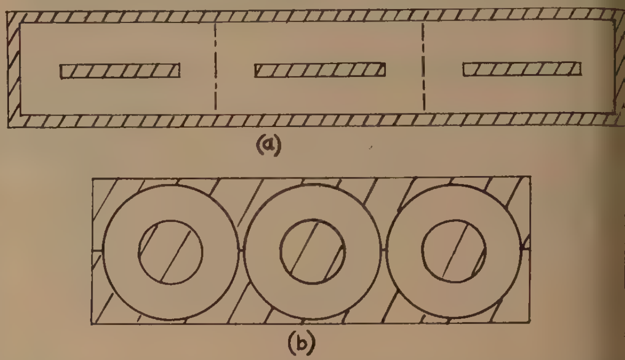

Figure 2 — Cross sections through 50-ohm strip-line and spli block-coaxial circuits proportioned to yield equal Q. Th three strips are spaced from each other by an amount tha provides about 40 db isolation.

An incompletely shielded form of photo-etched lin known as microstrip is shown in Figure 3. Because uses only one copper-clad dielectric sheet, it is more ec nomical to manufacture than the two-ground-plane phot etched line of Figure 1(a). However, in addition to diss pation losses comparable to that of Figure 1(a), the sem shielded microstrip line suffers from substantial radiati loss and stray-coupling effects. It is therefore less oft used now than the fully shielded types of strip line.

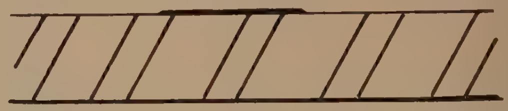

Figure 3 — Microstrip transmission line.

Design formulas and curves are available for the bas parameters of shielded strip line; namely, characteris impedance, attenuation, and Q[7a, 14, 15]. Data are also avai able on the parameters of parallel-coupled strip lines permitting the systematic design of directional couplers Approximate formulas and some experimental data ha been published for a number of strip-line discontinuiti such as changes in width, abrupt bends, Tee junctio series capacitive and inductive elements, etc.[44, 45a] B even with these approximate design data available, c

(*Continued on page 22*)

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3 mw full scale	–25 to –15dbm
mw full scale	–20 to –10dbm
mw full scale	–15 to –5dbm
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mw full scale	–5 to +5dbm
nw full scale	0 to +10dbm

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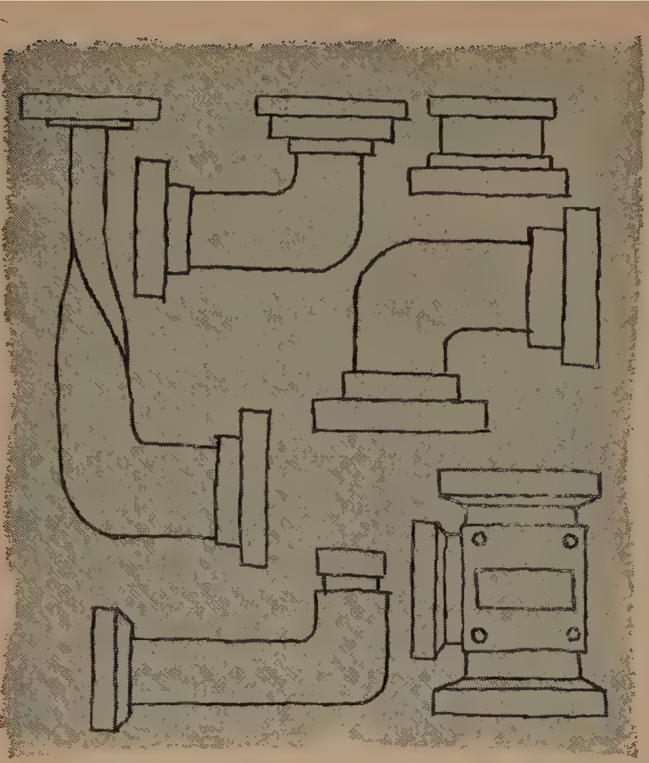

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(*Continued from page 20*)

siderable cut and try is necessary in developing mo strip-line components and circuits, especially if the highe quality of performance is required. This is also true coaxial line, but in some discontinuities, such as benc and Tee junctions, the perturbing effects seem less seve with comparable coaxial line, so that the task is easier.

Although strip line is particularly well suited for us in complete microwave circuits, designers have made e tensive applications of this type of construction in ind vidual components having coaxial connectors at the port This is most true of directional couplers and hybrid jun tions, in which excellent broad-band performance is easil achieved with strip line.[54a]

Also, strip line has found partial acceptance in man types of filters,[12, 17, 17a, 25, 39, 41a, 59] especially where s lectivity and VSWR requirements are not stringent, that filter elements are not critical. In such cases, comple low-pass, and band-pass filters may be photo-etched wit out the necessity of subsequent adjustment. Incorporatin tuning elements in dielectric-filled structures is particularl inconvenient, but in air-dielectric structures the difficul is no worse than with coaxial line. Some types of filte are beautifully adapted to strip-line construction, whi with many others the complexity and awkwardness arranging for isolation of elements, tuning, transitions, et make them better suited to a coaxial form. As eviden that the choice between strip-line and coaxial-line co struction in filters is not yet resolved, a number of filt manufacturers have restricted themselves entirely to coax line. Thus neither type of construction seems at th time to offer a definite competitive advantage—at lea not to the same degree as the experience and skill that into the development and production engineering of given filter.

The greatest promise of strip line is for economy, co pactness, and lightness in complete circuits such as receiv front ends, channel-separation networks, and power-divisi and phasing networks. Only the dielectric-filled, phot etched version offers strongly these advantages, and th only if a small ground-plane spacing such as 1/8 inch used. The relatively inferior uniformity and losses of t dielectric-filled, photo-etched line restrict it to applicatio where a larger than usual margin of error can be tolerate and where the advantages gained outweigh the disadva tages of additional power, amplification, or bandwid that might be needed in a given system to overcome t penalty of inferior performance and reproducibility. Ta ing these considerations into account, dielectric-filld photo-etched circuits are frequently, but not always, t best choice for microwave point-to-point communicati systems, and numerous microwave equipments for aircra missiles, and satellites. Where the highest quality of p formance is needed, as in radar systems, such circuits a not suitable, and either air-dielectric strip line, coax line, or waveguide is usually advisable.

In conclusion, the advantages and disadvantages of st line must be considered objectively in each individ application. Strip line has already won a solid posit that will undoubtedly grow. However, it most likely continue to play a minor rather than major role in competition with other forms of construction.

(*Continued on page 25*)

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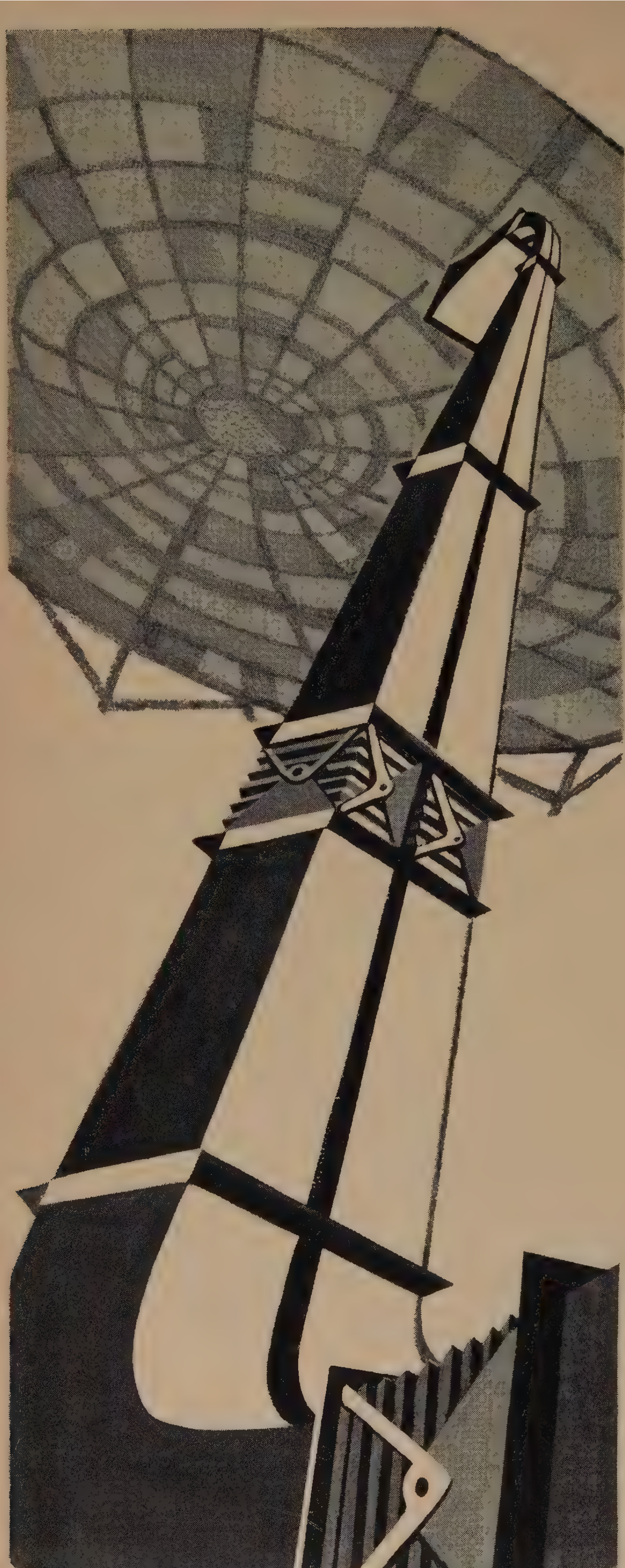

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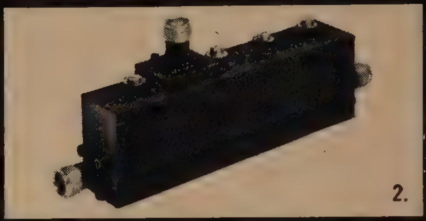
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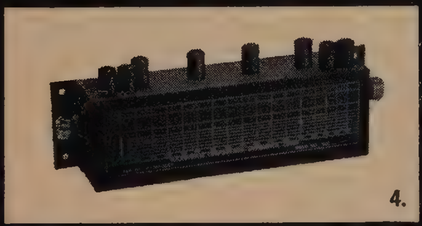
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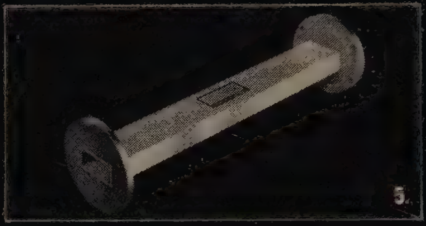
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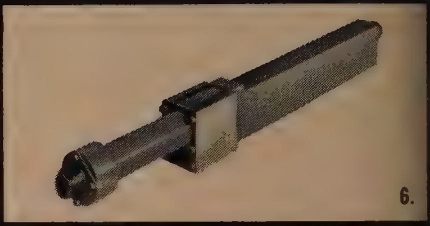
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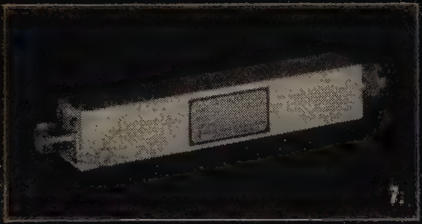
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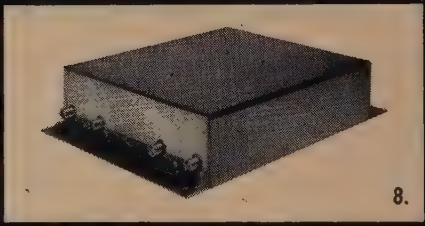
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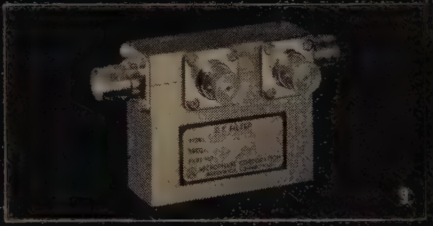
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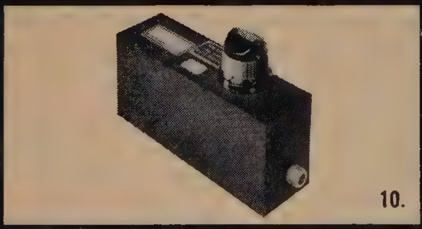
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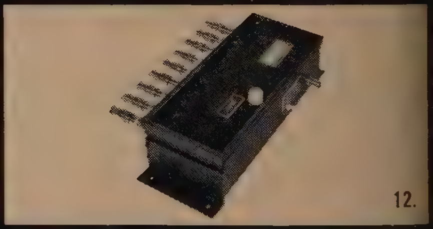
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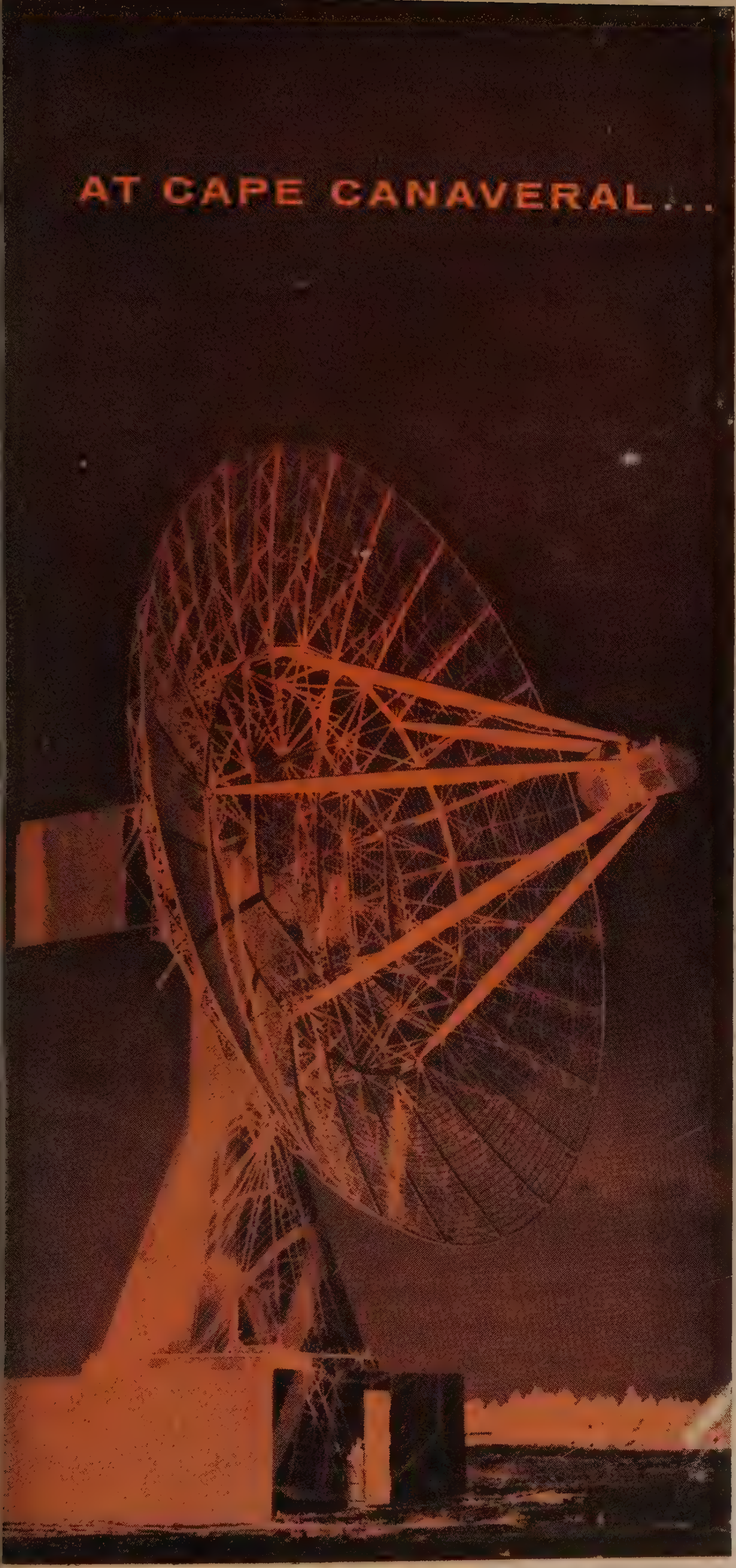

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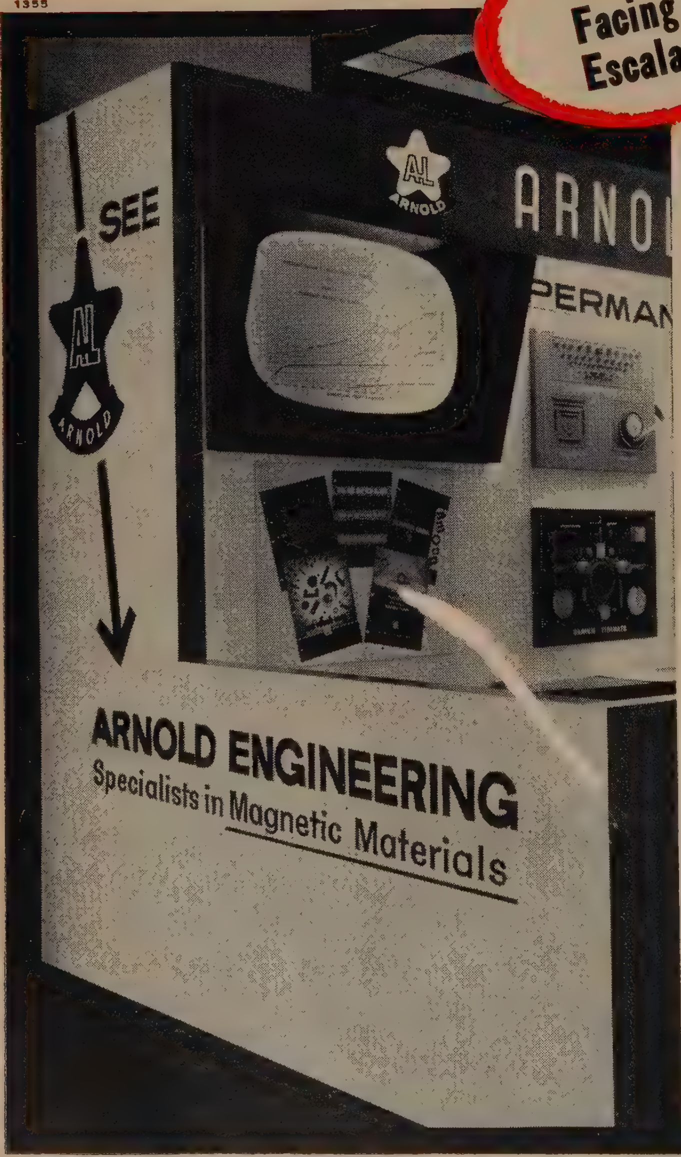

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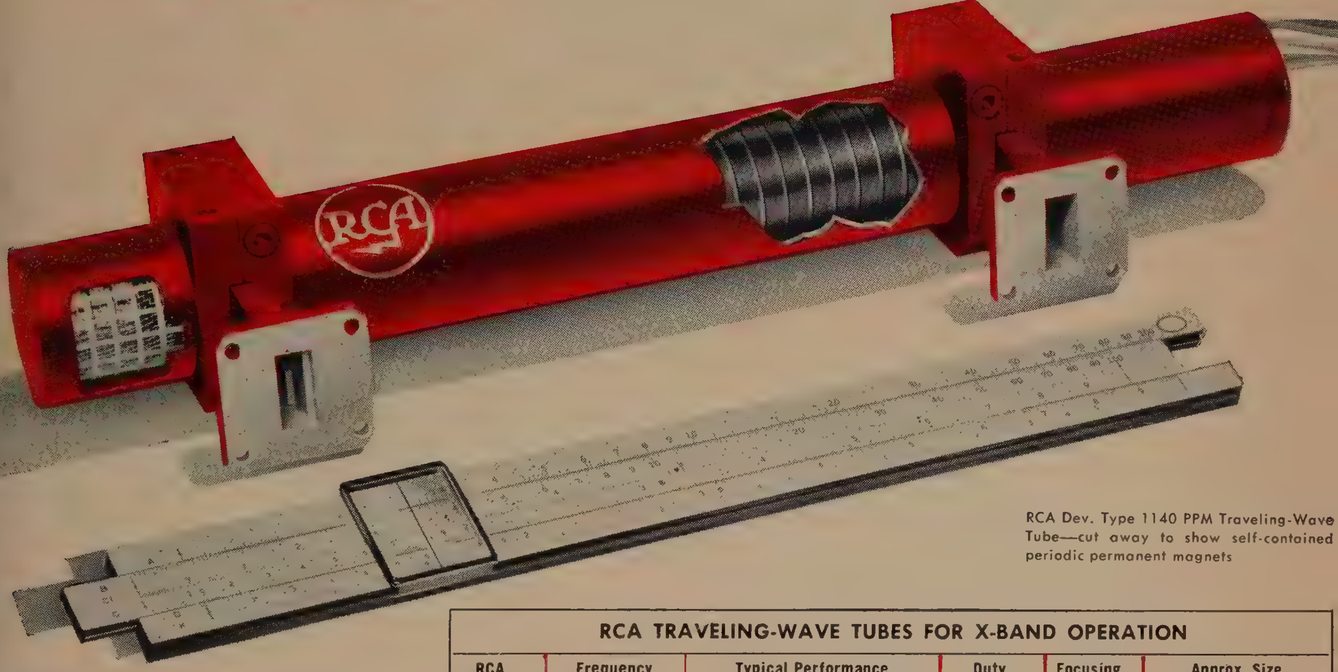

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		Power Output	Low-level Gain (db)			Weight (lb.)	Length (in.)
A-1140	8000-12000	10 mw	40	CW	PPM	5½	14
A-1133	8000-12000	1 w	35	CW	PPM	6	15
A-1181	7500-11200	50 peak watts	35	0.05	PPM	6	14

RCA Microwave-Tube Engineers invite inquiries for customized versions

RCA's continuing program to provide designers with a comprehensive and reliable line of traveling-wave tubes is exemplified by three new PPM focused X-band TWT's.

Focusing by means of Periodic Permanent Magnets makes possible more compact and lighter equipment designs. Waveguide couplings significantly reduce power loss, improve performance and efficiency in this complementary family of developmental X-band traveling-wave tubes for ECM, drone target systems, and radar applications. And all three tubes are designed for high-altitude airborne operation.

For traveling-wave tubes in any application in the L, S, C, and X bands, call the RCA Field Office nearest you. Your RCA Field Representative will be happy to give you detailed information on RCA commercial and developmental types—or customized versions—for your specific system needs.

GOVERNMENT SALES

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LOS ANGELES 22, CALIF.
6355 E. Washington Blvd., RAymond 3-8361

Visit the RCA Booths 1601-8, 1701-7
at the New York IRE Show

Circle Reader Service Card 23

RADIO CORPORATION OF AMERICA
Electron Tube Division **Harrison, N. J.**

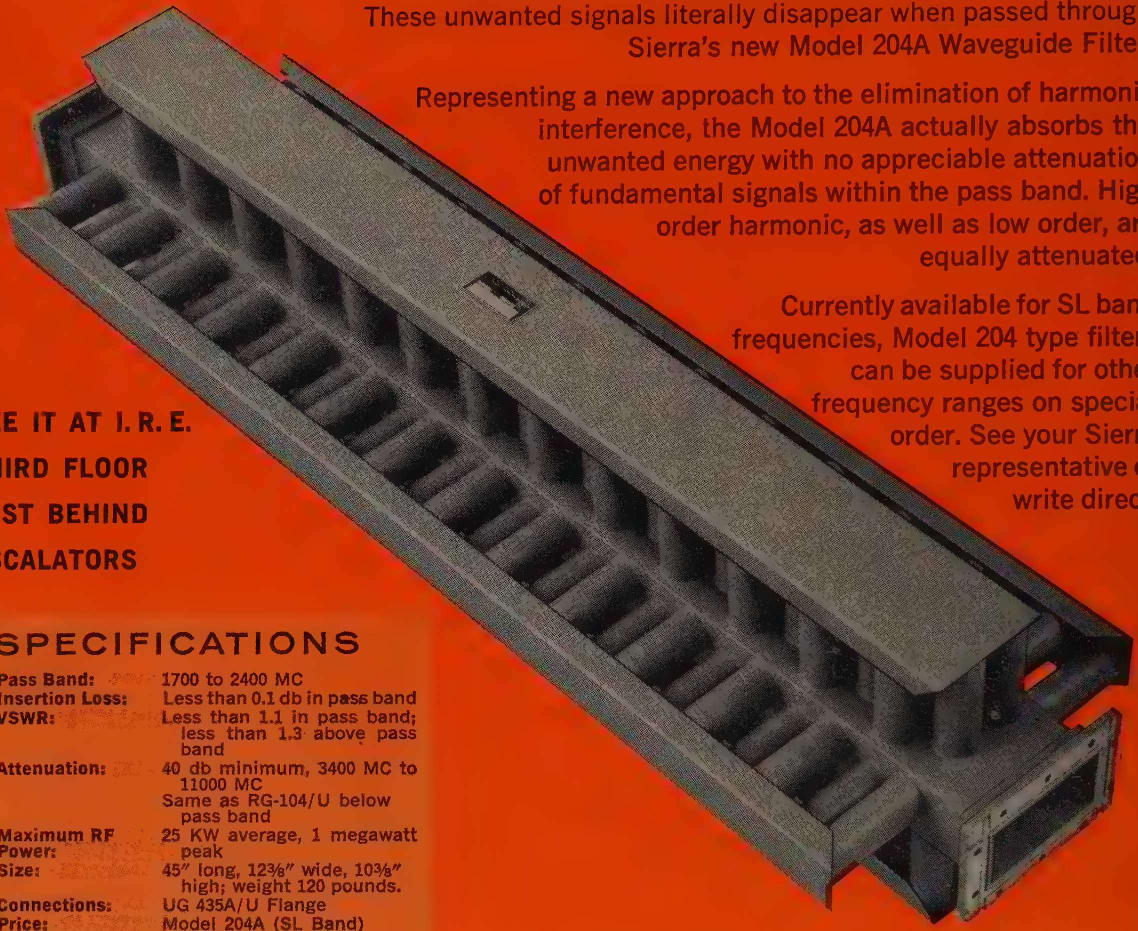
new high-power harmonic ABSORPTION filter for SL band—1700 to 2400 mc

Harmful harmonic interference from high-power microwave equipment should be, **and can be,** eliminated at the source. These unwanted signals literally disappear when passed through Sierra's new Model 204A Waveguide Filter.

Representing a new approach to the elimination of harmonic interference, the Model 204A actually absorbs the unwanted energy with no appreciable attenuation of fundamental signals within the pass band. High order harmonic, as well as low order, are equally attenuated.

Currently available for SL band frequencies, Model 204 type filters can be supplied for other frequency ranges on special order. See your Sierra representative or write direct.

SEE IT AT I. R. E.
THIRD FLOOR
JUST BEHIND
ESCALATORS

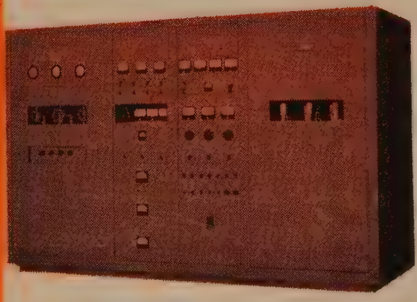


Sierra 204A SL Band Pass Filter

SPECIFICATIONS

Pass Band:	1700 to 2400 MC
Insertion Loss:	Less than 0.1 db in pass band
VSWR:	Less than 1.1 in pass band; less than 1.3 above pass band
Attenuation:	40 db minimum, 3400 MC to 11000 MC Same as RG-104/U below pass band
Maximum RF Power:	25 KW average, 1 megawatt peak
Size:	45″ long, 12⅜″ wide, 10⅜″ high; weight 120 pounds.
Connections:	UG 435A/U Flange
Price:	Model 204A (SL Band) $2,195.00

Data subject to change without notice



NEW 10 KW AND 1 KW KLYSTRON POWER AMPLIFIERS

Two klystron power amplifiers, Model 216A (10 KW output) and Model 217A (1 KW) are now available from Sierra. Both units employ 4-cavity klystron tubes, and are designed for scatter communications systems, space programs and high power point-to-point data transmission systems.

Both units are continuously tunable from 1700 to 2400 MC and as broadband amplifiers provide a minimum gain exceeding 40 db.

Except for its heat exchanger, Model 216A (10 KW, pictured) is housed in three connected cabinets. Its frequency bandwidth is 18 MC at ½ power points. Model 217A (1 KW), is housed in one cabinet. Its ½-power bandwidth is 15 MC. Write for details.

sierra

SIERRA ELECTRONIC CORPORATIO
A Division of Philco Corporation
6333 BOHANNON DRIVE • DAvenport 6-2060 • MENLO PARK, CALIFORNIA, U.S
Sales representatives in all principal areas
Canada: Atlas Instrument Corporation, Ltd., Montreal, Ottawa, Toronto, Vancouver
Export: Frazar & Hansen, Ltd., San Francisco, Los Angeles

Circle Reader Service Card 24

ow! heck out 4 aveguide anges in 5 minutes

The Turbo Variable-Step Microwave Delay Line is the first portable, reliable, and accurate means of testing responses of X-band delay line. Permits fast, accurate changing of 10 to 1500 feet of waveguide through the use of high isolation waveguide switches.

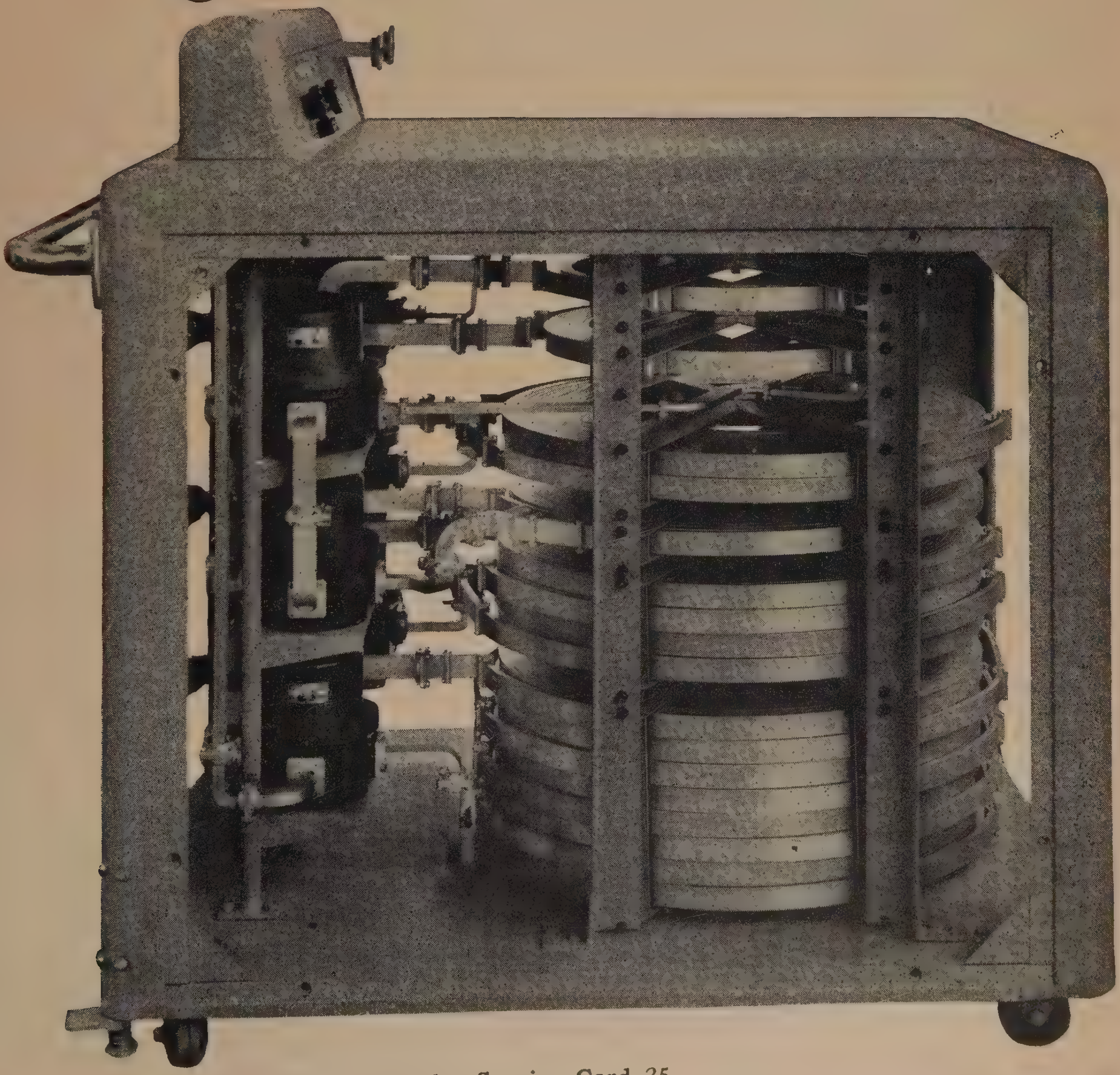
Formerly, two or more days were consumed in testing 64 different ranges using straight runs of waveguide . . . readings varied as amplifiers and other systems components drifted during a day-long check-out.

The new Turbo test stand eliminates coupling and uncoupling of joints, prevents contamination, saves time. Waveguide loops can be brought to the breadboards. This variable delay system can also be built into standard relay racks with a maximum of 2500 feet of X-band delay line.

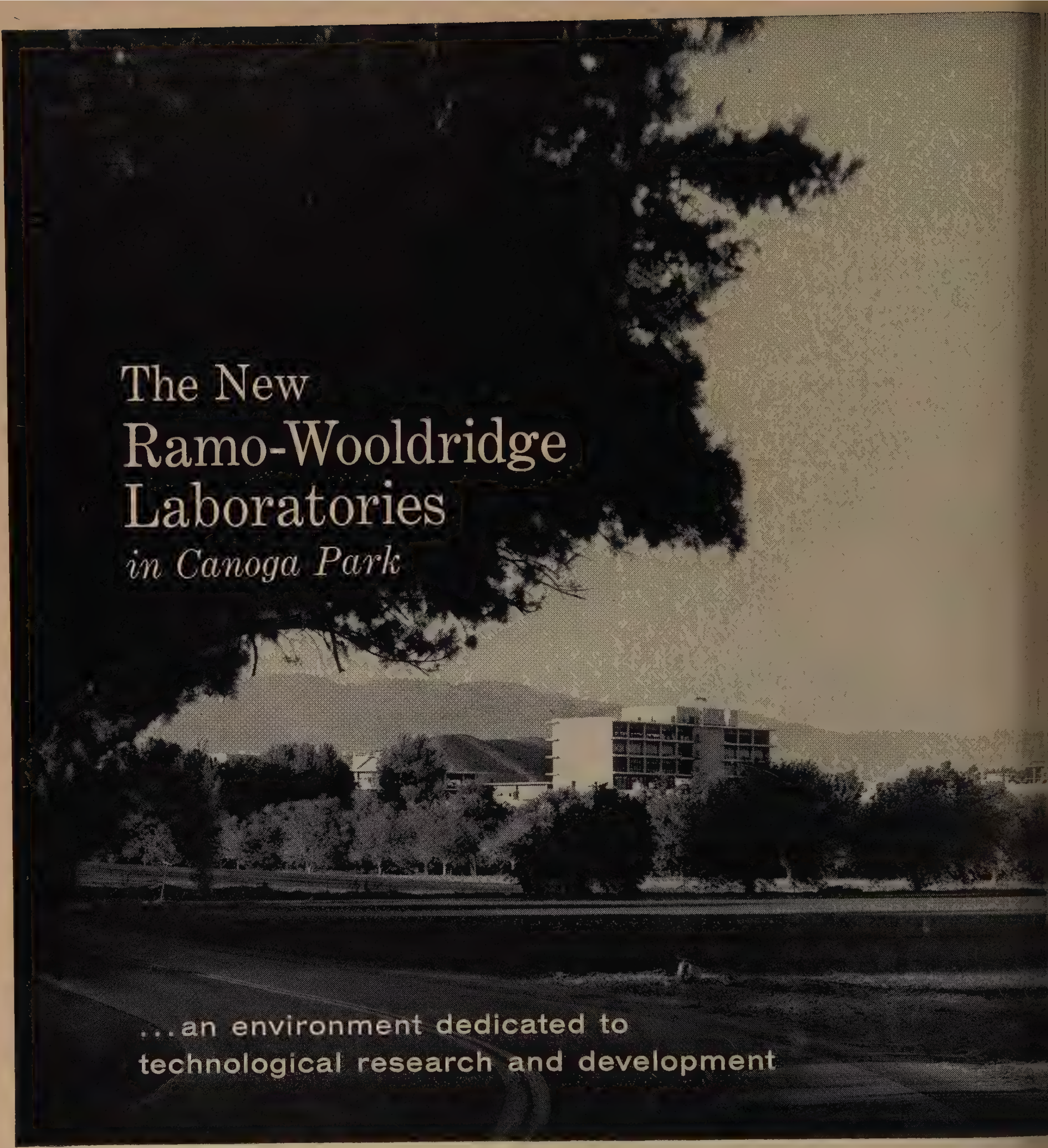
Turbo will furnish delay lines of any length or configuration to customers' specifications. Quotations furnished promptly on waveguide components and systems. Write for bulletin.

TURBO variable-step MICROWAVE DELAY LINE

TURBO MACHINE COMPANY, LANSDALE, PA.



Circle Reader Service Card 25


The New
Ramo-Wooldridge
Laboratories
in Canoga Park
...an environment dedicated to
technological research and development

The new Ramo-Wooldridge Laboratories in Canoga Park, California, will provide an excellent environment for scientists and engineers engaged in technological research and development. Because of the high degree of scientific and engineering effort involved in Ramo-Wooldridge programs, technically trained people are assigned a more dominant role in the management of the organization than is customary.

The ninety-acre landscaped site, with modern buildings grouped around a central mall, contributes to the academic environment necessary for creative work. The new Laboratories will be the West Coast headquarters of Thompson Ramo Wooldridge Inc. as well as house the Ramo-Wooldridge division of TRW.

The Ramo-Wooldridge Laboratories are engaged in the broad fields of electronic systems technology, computers, and data processing. Outstanding opportunities exist for scientists and engineers.

For specific information on current openings write to Mr. D. L. Pyke.

THE RAMO-WOOLDRIDGE LABORATORIES
8433 FALLBROOK AVENUE, CANOGA PARK, CALIFORNIA

U.S. NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

PART I

SEARCH FOR OUR NAVY AND OUR COUNTRY" might be the most appropriate way to summarize the role nature of the accomplishments of the Naval Re- ch Laboratory during its 37 years of existence.

lthough the Laboratory is perhaps best known as "birthplace of radar," its scientific work is far restricted to the single field of electronics, which mpasses radar. More than a thousand scientists loyed in the Research Department are at work on and technological problems involving the major s of the physical and engineering sciences. The es of the scientific divisions at NRL provide an llent indication of the scope of the Laboratory's rch programs: Applications Research; Atmosphere Astrophysics; Chemistry; Electronics; Mechanics; llurgy; Nucleonics; Optics; Radar; Solid-State; d; and Radiation.

ory

he establishment of the Laboratory, known initially he Naval Experimental and Research Laboratory, the result of a 1915 recommendation by a Naval Consulting Board. The Board, headed by Thomas A. Edison, envisioned a Laboratory managed and administered by the Navy with the scientific program conducted by civilians. World War I delayed action on the Board's recommendations, and it was not until 1920 that the ground was broken for the first building. The Laboratory was officially commissioned with appropriate ceremony on July 1, 1923. Assistant Secretary of the Navy, Theodore Roosevelt, Jr., was the principal speaker.

Compared with today's standards, the Laboratory's work in the early days was performed under very modest circumstances. There were only four major buildings — the Administration Building in which the scientific laboratories were located, the Machine Shop, the Foundry, and the Heating Plant and Power House. The station grounds covered about 27½ acres. Three small research groups working in Washington and one at the Engineering Experiment Station in Annapolis — about 20 men in all — moved to the newly-established Naval installation, located near the southwest tip of Washington. Later in the initial year, the staff

Aerial view of some of the 92 buildings which house the Naval Research Laboratories.

CAPT. ARTHUR E. KRAPF
Commander, U.S. Naval Research Laboratory

DR. ROBERT M. PAGE
Director of Research

filled out to four officers and 92 civilians. These groups comprised the only two scientific divisions — Radio and Sound. Their early research was directed chiefly toward the improvement of radio apparatus and underwater sound detection gear used aboard ships.

During the years new divisions were gradually added to the Laboratory's program, widening the scope of its activities. By 1935, there were seven — Radio, Sound, Physical Optics, Mechanics, Metallurgy, Chemistry, and Interior Communications.

A Modest Laboratory Becomes the Center of Activity

When war came in 1941, NRL changed almost overnight from a fairly modest laboratory into one of the greatest research institutions in the world. Fortunately, it had had 18 years in which to grow.

Personnel increased from 396 in 1941 to about 4,400 in 1945. There was a substantial temporary increase in the number of military personnel, owing to the number of visiting activities such as the Radio Material School. The number of buildings also increased from 23 to 67, and annual expenditures rose from 1.7 to 13.7 million dollars. The number of research problems assigned to the Laboratory increased from about 200 to nearly 900.

NRL Facilities

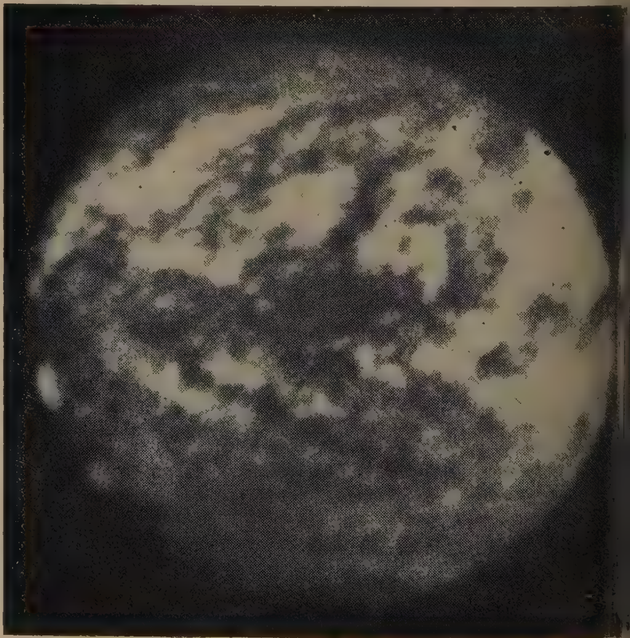
Today NRL occupies 59 acres and 92 buildings and has 13 research divisions. Approximately 1,500 men and women are engaged in research with about the same number in supporting groups.

A wide variety of highly sophisticated implements and facilities for its numerous research programs are located at the main establishment, the Chesapeake Bay Annex, and other special purpose sites. CBA's facilities include equipment for evaluating automatic fire-control and tracking radar for shipboard use. A transonic whirling arm for evaluating aircraft meteorological instruments, and an assortment of apparatus for conducting special studies in the fields of sound, radio mechanics, and optics is included. It is an ideally located site for instruments used in such optical studies as the atmospheric transmission of light.

A thriving segment of NRL lies almost 3000 miles from Washington in the Panama Canal Zone. Excellent laboratories and field exposure facilities are maintained for studying the tropical deterioration of materials and equipment. One is the Corrosion Laboratory at Miraflores. The other is the Tropical Exposure Sit at Coco Solo. Both long and short-range studies ar carried on at these facilities to provide much neede quantitative data, aimed toward producing material and equipment of outstanding resistance to corrosio and deterioration by marine and tropical environments

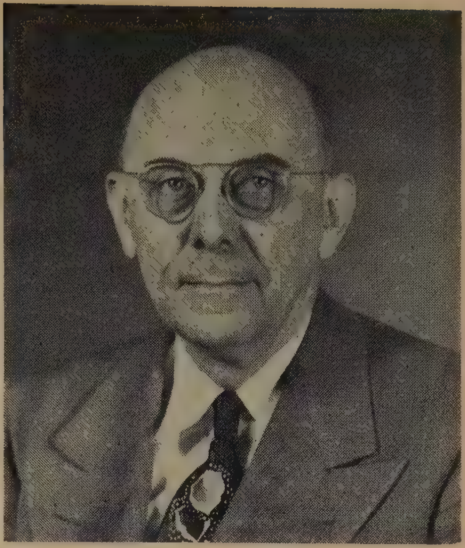
One of NRL's newest facilities is the Maryland Poin Observatory, located on the Potomac River in Charle County, Maryland. This is the site of the Laboratory'

First detailed photograph of the sun exposed by ultraviole radiation camera mounted in rocket. See text.



ALLEN SCHOOLEY
Associate Director of Research for Electronics

LOUIS A. GEBHARD
Superintendent — Radio Division



foot radio telescope, one of the largest equatorially
unted installations in the world.

An even more recent addition is SPASUR, a net-
k of space surveillance stations stretching across
southern part of the United States. Under the
pices of the Advanced Research Projects Agency of
Department of Defense, NRL designed and estab-
ed the network to detect the presence of silent
llites. The network of SPASUR Stations is com-
sed of two complexes. In each complex there is
enter station which transmits a continuous thin
of energy vertically and in line with the two
iving stations located approximately 250 miles from
transmitter. Energy in the "fan" is reflected from
satellite to the receivers and automatically recorded.

he SPASUR Stations in the eastern half of the net-
k are located at Jordan Lake, Alabama; Fort Stew-
Georgia; and Silver Lake, Mississippi; those in
western half are located at Gila River, Arizona;
wn Field, California; and Elephant Butte, New
xico.

For diverse research problems requiring specialized units that are not produced commercially, NRL maintains complete engineering shop facilities, which are capable of making limited quantities of such equipment required by the scientists. The Laboratory also has provision for complete fabrication of electronic tubes for experimental purposes.

The People

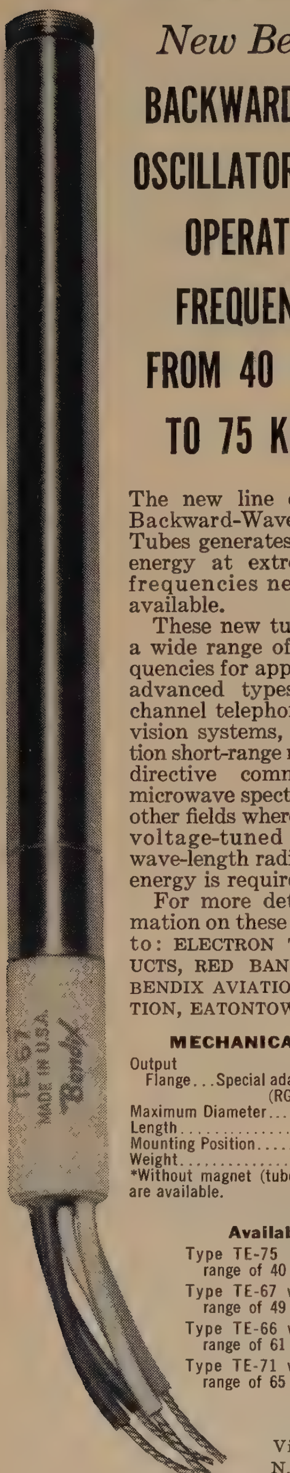
The internal organization of NRL has always followed the pattern conceived by the Naval Consulting Board in 1915 — a laboratory under Navy management, staffed by civilian scientists.

Naval officers serve tours of duty of two to four years. Outgoing officers carry back to the Fleet an enriched appreciation of the Laboratory's scientific program, and replacement officers coming directly from the Fleet bring to the Laboratory the immediate problems and operating experiences of the Navy in the air, afloat, and under the sea.

The research department is permanent and afforded full authority and responsibility for its scientific

DR. JOHN I. BOHNERT
Superintendent — Electronics Division

DR. ROBERT C. GUTHRIE
Superintendent — Radar Division



ONE IN A SERIES

Bendix Craftsmanship at work for you

New Bendix

BACKWARD-WAVE OSCILLATOR TUBES OPERATE IN FREQUENCIES FROM 40 KMC/S TO 75 KMC/S

The new line of Bendix® Backward-Wave Oscillator Tubes generates microwave energy at extremely high frequencies never before available.

These new tubes provide a wide range of usable frequencies for applications in: advanced types of multi-channel telephone and television systems, high definition short-range radar, highly directive communications, microwave spectroscopy and other fields where low power, voltage-tuned millimeter wave-length radio frequency energy is required.

For more detailed information on these tubes, write to: ELECTRON TUBE PRODUCTS, RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, N. J.

MECHANICAL DATA

Output Flange...Special adapter to RG-98/U (RG-97/U for TE-75)
Maximum Diameter.............0.625"
Length..........................8"
Mounting Position................Any
Weight........................5 oz.*
*Without magnet (tube only). Magnets are available.

Available types

Type TE-75 with frequency range of 40 Kmc to 50 Kmc
Type TE-67 with frequency range of 49 Kmc to 59 Kmc
Type TE-66 with frequency range of 61 Kmc to 71 Kmc
Type TE-71 with frequency range of 65 Kmc to 75 Kmc

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N.Y. IRE Show
Booth 2228

ELECTRON TUBE PRODUCTS

Red Bank
Division

Bendix
AVIATION CORPORATION

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work. This department is headed by a civilian director of research who has three associates, one each for the fields of electronics, materials, and nucleonics. It is separated further into 13 divisions with their own civilian scientists as superintendents. The branches within these divisions form small, tightly knit, yet inter-related, working units, each concerned with research, development, and evaluation in a specific area of the physical and engineering sciences.

Scientists and engineers at NRL are permitted to expand their own capabilities and pursue their own ideas. They work in an atmosphere close to that of a university, an environmental influence conducive to the best efforts in either pure science or applied research.

The Scientific Program

A program to "investigate the physical phenomena in, and the properties of, the upper atmosphere" was established in 1945. About 80 experiments were performed with captured V-2 rockets, used to carry research instruments aloft. The NRL experiments were successful in providing new data on the temperature, pressure, and composition of the earth's upper atmosphere, the earth's magnetic field, the ionosphere, the solar ultraviolet spectrum, and cosmic rays. Other rockets used in the long-range program, after the supply of V-2's became exhausted, included the NRL Viking, the Aerobee, and the Aerobee-Hi.

The most "sophisticated" rocket developed at NRL for research during the IGY, of course, was the Vanguard. On March 17, 1958 the scientists of NRL's Project Vanguard launched a Test Vehicle. This placed a satellite in the highest and most stable orbit achieved to date. The satellite is expected to remain in orbit for over 200 years. It was equipped with solar batteries, an experiment in itself. As a result, transmission has been steady for over a year and is expected to go on indefinitely. Much scientific information is being gathered from Vanguard I regarding air density temperature ranges, and micrometeorite impact. Because of its stable orbit, islands in the Pacific can be relocated properly on the map. The shape of the earth has been found to be pear-shaped. This is obviously, somewhat different from the previously prevailing idea of the earth being spherical.

By employing rocket-astronomy techniques to send "observations" far above the dense layer of the earth's atmosphere, it has been possible to get a new and revealing look at the sun and other celestial bodies or constellations. Within the past decade rocket astronomy has furnished a first look at the solar spectrum from the visible to far into the X-ray region. This has revealed the existence of vast clouds of ultraviolet nebulosities in the night sky. A major interest in this research is the effect of solar radiations on the ionosphere and various layers of the earth's atmosphere.

A spectacular episode took place in the Danger Islands area of the South Pacific during the solar eclipse in October 1958. NRL scientists launched six instrumented rockets from shipboard; one immediately preceding and four during the eclipse, and one after the eclipse From data radioed back to the ship scientists found what was suspected but not confirmed — that the ultraviolet rays come from the sun's surface while the X-rays come from the hot, gaseous atmosphere, or corona, around the sun.

A major achievement in rocke astronomy took place on March 13 1959. NRL scientists obtained th first detailed photograph of the entire sun taken in the light of extreme ultraviolet radiation. Th photograph was made with a camer specially designed at NRL. It wa installed in the nose cone of a Aerobee-Hi rocket, which soare 123 miles above the White Sand Missile Range in New Mexico. Th camera itself took four years to construct and was made with speci mirrors ruled with a grating of fi lines, 15,000 to the inch, to filt out the intense visible light from th sun.

Photography of the sun in power- l short-wave length light repre- nts a tremendous advance toward nderstanding the relationship be- veen solar activity and its effect on e earth's atmosphere.

adio Astronomy

NRL investigations in radio as- onomy, a relatively new and re- arding basic research program, so date from 1946. Under this ogram NRL astronomers observe d study the radio emissions from e sun, planets, and stars. The stud- s are conducted with radio tele- opes ranging from 10 to 84 feet diameter. In the future the pro- am will be augmented by a 600- ot radio telescope at the Naval adio Research Station, now being nstructed on a knoll in the Alle- any Mountains, near the town of gar Grove, W.Va. The seventy- ne million dollar facility was con- ived at NRL and is scheduled for mpletion in 1962. Until that date e Laboratory will maintain tech- cal supervision of the project. The dio astronomy program already s contributed a great deal of new formation about planetary radia- n, temperatures, our galaxy, and e universe. One of the more excit- g prospects of this continuing sic research program, especially er completion of the 600-foot dio telescope, which has a theo- ical range of many billion light ars, is the possibility of acquiring urate data on dimensions of the iverse.

RL Today

NRL stands today as one of the remost physical research labora- ries in the world. In all three of major fields of endeavor — elec- nics research, materials research, d nucleonics research — its pro- am is geared to discovery. In the ld of microwaves as well as roughout its wide program, its g record of innovation in preci- n components, research instru- nts, and operational systems rms a sound basis of promise of en greater things to come.

(To be Concluded in the April Issue.)

ONE IN A SERIES

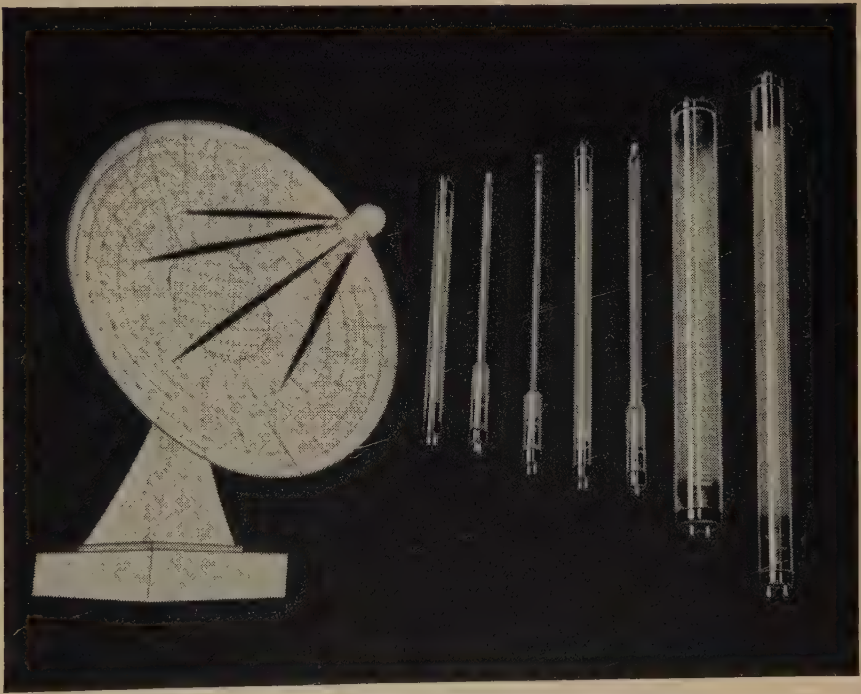
Bendix Craftsmanship at work for you

WIDEST RANGE OF MICROWAVE GAS NOISE SOURCES AVAILABLE ANYWHERE

Since accurate measurement of a receiver's inherent noise level is vital in determining a value for absolute signal level for a given signal-to-noise ratio, it stands to reason that the noise source tube used should fit the specific job requirements exactly.

The tremendous variety—biggest in the industry—of Bendix® Microwave Gas Noise Source Tubes is your best guarantee of matching noise sources to the application—whether that application be in the laboratory, in field service, or as a component of the system.

Our new improvements in design make Bendix tubes suitable for use in pulse circuits with an increase of one order of magnitude in life. And our improved manufacturing techniques have resulted in a smaller spread of excess noise output from tube to tube. Many Bendix types are now available to a tolerance of ± 0.1 db on excess noise output.



Complete engineering data on the Bendix Microwave Noise Source Tube line and on auxiliary circuit designs can be obtained by writing . . .

SPECIAL-PURPOSE TUBES DEPARTMENT
Red Bank Division
EATONTOWN, NEW JERSEY

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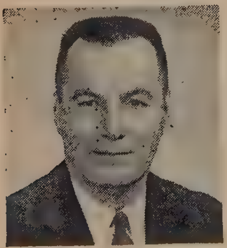
INTRODUCING

ANTENNA SYSTEMS INC.

A new corporation devoted exclusively to the design, fabrication and installation antenna systems in the fields of scatter communications, missile tracking, spa tracking, radar and surveillance, radio astronomy and special antenna produc



A word from the new president, Charles Creaser . . . "Ours is primarily an engineering organization which is employee-owned and employee-run. Our objective can be stated simply: it is to lead in the development and introduction of new and improved techniques and processes. We are equipped to handle the entire antenna system — reflectors, mounts, feeds, pedestals, waveguide, rotary joints — everything from transmitter and receiver on."

. . . and from the vice-president, Bill VanderWolk "We're off to an exciting start. We've taken a new approach to antenna marketing by building a new, 30-foot parabolic dish for space tracking and communications, which promises to be more accurate than anything yet built. Very soon, we'll have the finished product, built and operating, to show to industry and government. Instead of offering a design and a promise of performance, we'll prove ours first."

For more information, please send for our folder

ANTENNA SYSTEMS INC. Hingham Industrial Center, Hingham, Mass.

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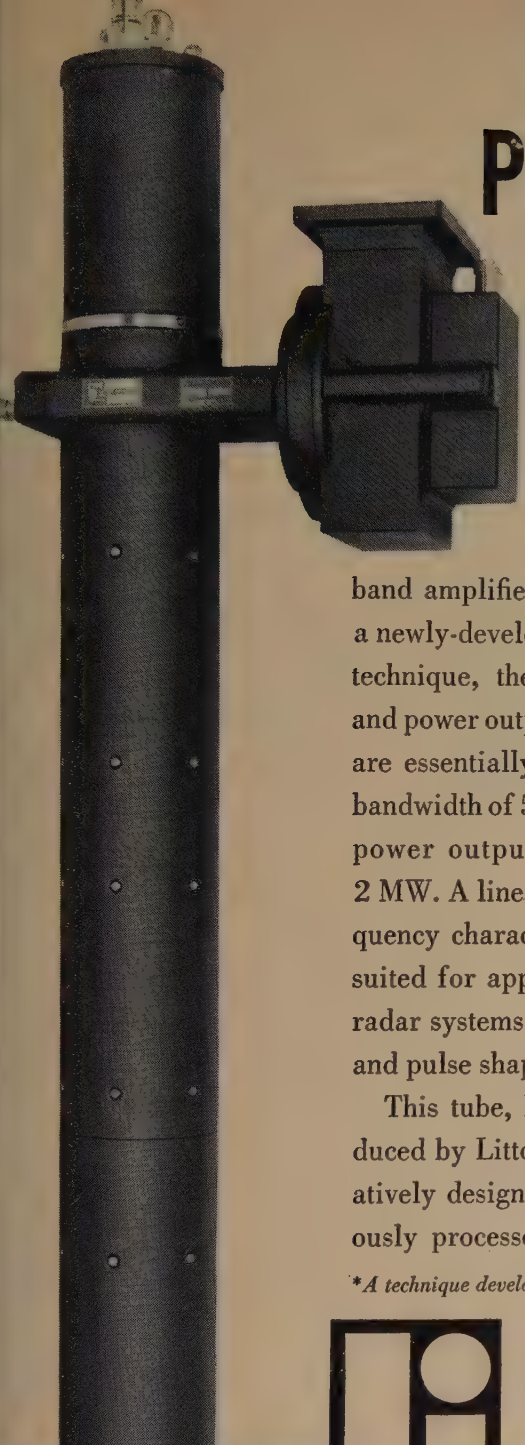

L-BAND KLYSTRON PROVIDES BROADBAND PERFORMANCE

This addition to Litton Industries' Klystron family introduces a new concept in broadband amplifier tubes. Through use of a newly-developed Skirtron* bunching technique, the L-3283 achieves gain and power output characteristics, which are essentially flat over the minimum bandwidth of 50 Mc. Its minimum peak power output at the band edges is 2 MW. A linear phase shift versus frequency characteristic makes it ideally suited for application in sophisticated radar systems, where electronic tuning and pulse shaping are required.

This tube, like all other tubes produced by Litton Industries, is conservatively designed and rated; and rigorously processed to provide thousands of hours of reliable operation. Typical of the performance obtained from applying this design philosophy is that of the L-3035, a 2.2 MW L-band Klystron, whose *average* operating life in field service is approaching 3,000 hours. Some of these tubes are continuing to provide top performance after operating for more than 10,000 hours.

The Skirtron technique is being applied to other tubes now being developed to obtain even broader-band performance at higher power levels and in other frequency ranges. Should you require high power broadband performance for your current (L-3283 is available now) or future system planning, write to Litton Industries, Electron Tube Division, Office M 11, 960 Industrial Road, San Carlos, California.

A technique developed by Litton Industries which provides improved broadband performance.

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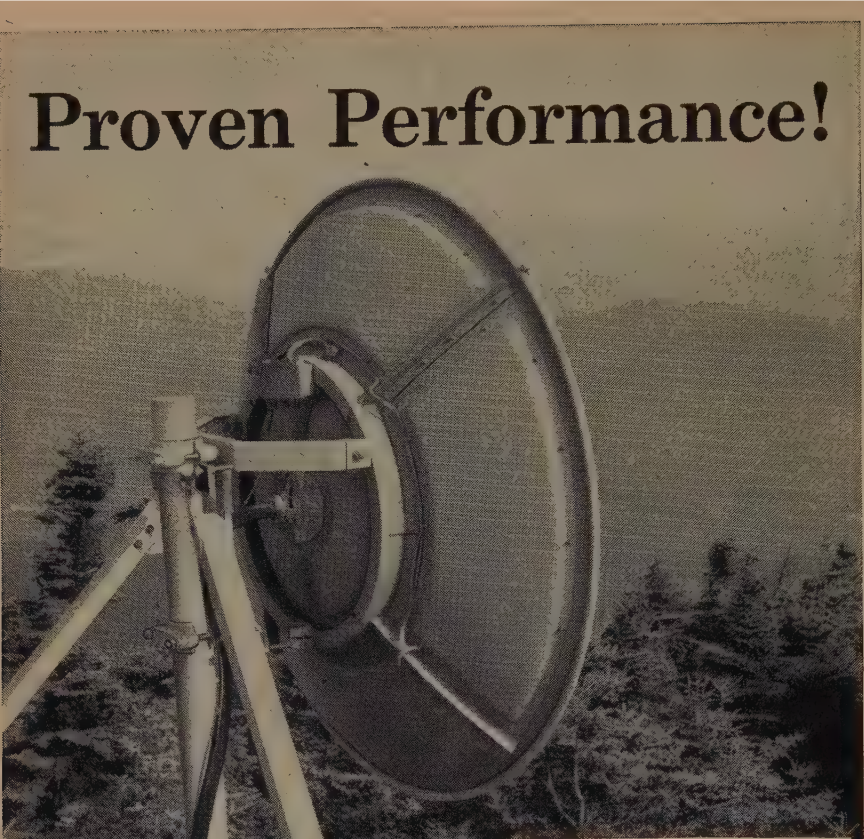
LITTON INDUSTRIES Electron Tube Division

BARRATRON TRANSMITTINC TUBES • MAGNETRONS • KLYSTRONS • TRAVELING WAVE TUBES • BACKWARD WAVE OSCILLATORS • CARCINOTRONS • GAS DISCHARGE TUBES NOISE SOURCES • CROSSED-FIELD AMPLIFIERS • HIGH DEFINITION CRT • DIRECT-WRITING CRT • COLOR CRT • STORAGE TUBES • MICROWAVE FILTERS • DUPLEXERS • TR TUBES

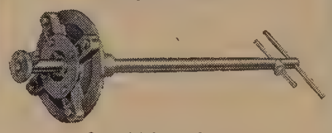
CAPABILITY
THAT CAN CHANGE
YOUR PLANNING

Proven Performance!



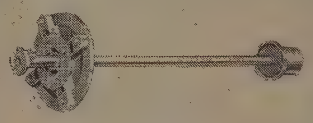
View of microwave installation atop Mount Pico, Vermont. Altitude 4,000 feet.

DIPOLE FEED



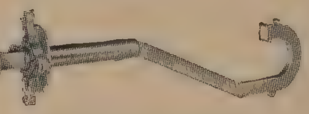
for 400-960 mc

COAXIAL HORN FEED



for 1700-2700 mc

WAVEGUIDE HORN FEED



for 3700-13,200 mc

ANDREW

. . . proven performance, where rough conditions are normal all year. Here is a high mountain-top tower where ANDREW equipment was installed to perform, exposed to 100 mph winds, driving sleet, ice and snow.

Selection of the best antenna systems for such problem installations is made easy through a choice of 30 ANDREW stock parabolic reflectors, which utilize the three standard microwave feeds. And tower work has been simplified too, with the new mount, which has separate elevation and azimuth adjustments for precise alignment.

All standard ANDREW antennas meet or surpass EIA recommendations and FCC specifications, governing radiation patterns and side lobes.

Uniform all weather performance is assured by the use of radomes and built in automatic de-icing equipment.

Why not check today on how you can get the maximum performance in your installation—just call the ANDREW Engineer in your area or write

Andrew
CORPORATION
363 EAST 75th STREET • CHICAGO 19
Offices: Chicago • Los Angeles • Boston
New York • Washington, D. C. • Toronto

ANTENNAS, ANTENNA SYSTEMS, TRANSMISSION LINES

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Displaying 6 kmc dual polarized antenna system and the new HUBLOC antennas.

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INDUSTRY NEWS

NATIONAL ELECTRONICS CONFERENCE CALLS FOR PAPERS

The National Electronics Conference wil be held at the Sherman Hotel, Chicago Illinois, on October 10, 11, and 12, 1960.

Authors of papers are invited to submi abstracts of 100 to 150 words (for publication in program) and either a 400 to 500 word summary or the completed paper fo review. Submit to:

Professor Thomas F. Jones, Jr., Program Chairman, NEC, School of Electrical Engineering, Purdue University, Lafayette, Indiana.

Technical areas typical of those covered at the Conference include:

Adaptive Servomechanisms; Antennas and Propagation; Audio; Circuit Theory; Communication Systems; Computers; Information Theory; Instrumentation and Telemetry Masers; Microminiaturization; Microwaves Millimeter Waves; Parametric Amplifiers Plasma Research; Radar and Radio Navigation; Radio Astronomy; Servomechanisms Signal-Matched Filters; Solid-State Circuits Solid-State Devices and materials; Spac Electronics, Communications and Navigation; Television; Transistors; Value Engineering.

— *mwj* —

1960 BOULDER CONFERENCE SLATED FOR JUNE 22-24

The very successful conference held a Boulder in the summer of 1958 stimulate the desire on the part of many of the 90 conferees that another should be held withi a year or two. Since the 1958 Conferenc there has been an intensified interest in th development of standards and measuremen techniques, stemming mainly from defens requirements and the specialized needs c the space age. Many new laboratories hav come into existence during the past severa years, as a part of the standards and calibration programs within industry and amon the defense agencies. The upsurge in nee for greater accuracy and extended range, a well as wholly new measurement technique has multiplied the problems of those working in the field of electronic standards.

The 1960 Conference will be co-sponsore by the IRE Professional Group on Instrumentation, the Radio Standards Laborato of the National Bureau of Standards, an the AIEE Instrumentation Division. Th Conference will provide a broad review o the most recent developments and accompanying problems throughout the usefu frequency spectrum of contemporary application.

Again the Conference will be held i Boulder, Colorado, scheduled in June rath than August. The season is more pleasan the scenery more beautiful, and the area le crowded.

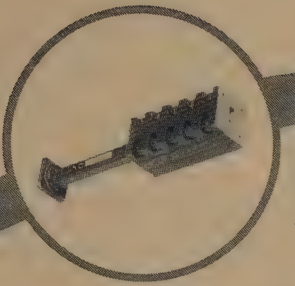
TECHNICAL SESSIONS

I. Current and Future Problems i Standards and Electronic Measur ments:

Chairman: Lloyd B. Wilson, Spe ry Gyroscope Company, Great Nec New York.

AEL®

ON THE CREST OF THE MICROWAVE



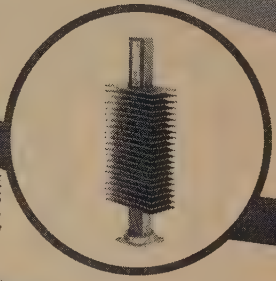
WAVEGUIDE FILTERS
"Waffle Iron"—band pass High Pass • Waveguide Cavity 8.2 kmc/s—40 kmc/s • extremely low pass band insertion loss

CONICAL HELIX AND LOG PERIODIC ANTENNAS
Broad Band 20:1 • Circularly or linearly polarized • 40 mc/s to 12,000 mc/s

. . . with an unusual line of new Microwave Components.

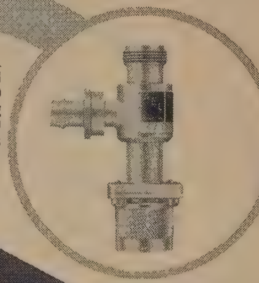
New concepts in Microwave development and manufacture are setting new standards in the state of the art.

Shown here is part of AEL's well-balanced Microwave line that was designed to agree with your system.



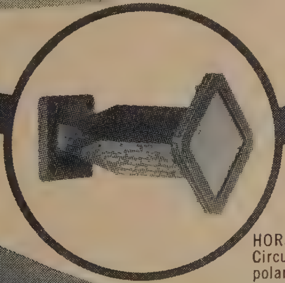
WAVEGUIDE DUMMY LOADS
Low VSWR • Lightweight • High Power • High Efficiency

See us at the IRE Show Booth 3935 . . .

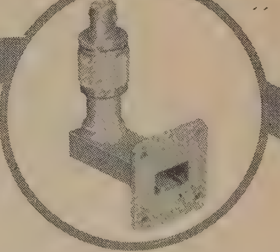


COAXIAL MICROWAVE SWITCH
30 mc/s to 12,000 mc/s • Switching speeds faster than 10 millimicroseconds

COAXIAL CRYSTAL DETECTOR MOUNTS
50 mc/s to 12 kmc/s • Broad band—Octave band—Narrow band • −50 dbm to −65 dbm Tangential Sensitivity



HORN ANTENNAS
Circularly and Linearly Polarized • Circular polarization—4 kmc/s to 40 kmc/s waveguide feed • linear polarization—1 kmc/s to 12 kmc/s coaxial feed



WAVEGUIDE CRYSTAL DETECTOR MOUNTS
8.2 kmc/s to 40 kmc/s • Standard waveguide sizes—aluminum • Highest Tangential Sensitivities available

Additional Items Include:
Crystal Detector Mount Heaters
Coaxial DC Blocks and DC Returns
Harmonic Generators

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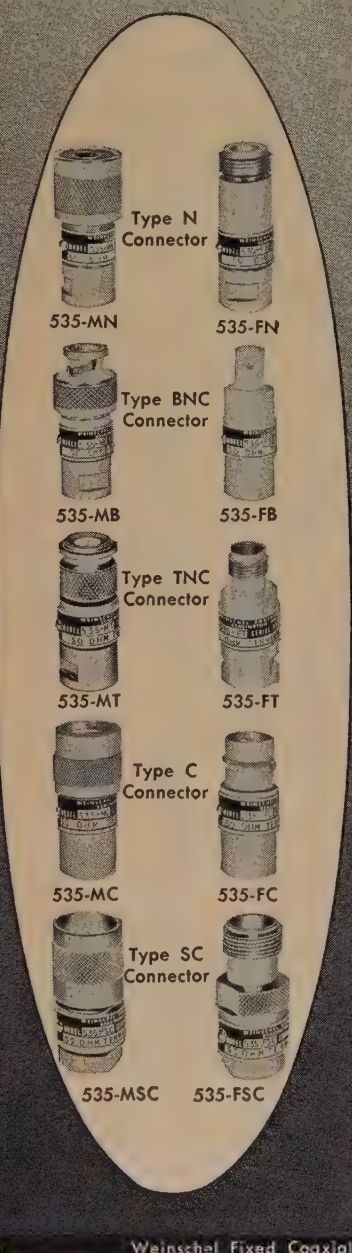
COAXIAL TERMINATIONS

DC to 10 KMC
50 ohms

Connectors: N, C, SC, BNC and TNC
Individual VSWR calibrations supplied at seven frequencies: DC, .4, 1, 2, 4, 7.5 and 10 KMC.
Made with Weinschel Film Resistors for maximum stability.



WE CO

Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12.4 KMC. Write for complete catalog.

Weinschel Engineering
KENSINGTON, MARYLAND

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Industry News

(*Continued from page 42*)

II. Direct Current and Low Frequency Standards and Calibrations:
  Chairman: William G. Amey, Leeds and Northrup Company, Philadelphia, Pennsylvania.

III. Methods of Measurement for Materials:
  Chairman: John L. Dalke, National Bureau of Standards, Boulder, Colorado.

IV. Frequency and Time Standards:
  Chairman: Roger A. Sykes, Bell Telephone Laboratories, North Andover, Mass.

V. Microwave Standards and Calibrations:
  Chairman: Milton Magid, FXR Inc., Woodside, New York.

VI. High Frequency Standards and Calibrations:
  Chairman: Robert A. Soderman, General Radio Company, West Concord, Mass.

— *mwj* —

URSI-IRE SPRING MEETING

The URSI-IRE spring meeting will be held at the Sheraton Park Hotel and the National Bureau of Standards, Washington, D.C., May 2-5. The IRE Professional Groups on Antennas and Propagation, Circuit Theory, Information Theory, Instrumentation and Microwave Theory and Techniques are cosponsoring the meeting.

The U.S. National Committee, URSI, will hold a business meeting on Monday morning, May 2. A combined technical session for all participants will be held on Monday afternoon, and the Commissions will hold their business sessions on Monday and Tuesday evenings.

The following Commissions are planning to hold one or more technical sessions in addition to their business meetings:

Commission 1. — Radio Measurement Methods and Standards — R. W. Beatty, *Chairman;* Commission 2. — Tropospheric Radio Propagation — Irwin H. Gerks, *Chairman;* Commission 3. — Ionospheric Radio Propagation — L. A. Manning, *Chairman;* Commission 4. — Radio Noise of Terrestrial Origin — William P. Crichlow, *Chairman;* Commission 5. — Radio Astronomy — E. F. McClain, *Chairman;* Commission 6. — Radio Waves and Circuits — John I. Bohnert, *Chairman.*

— *mwj* —

LYNCH CARRIER SYSTEMS CHANGES NAME

Signaling the expansion into the general field of communication and remote control, the stockholders of Lynch Carrier Systems Inc., at their annual meeting at the Company's plant in San Francisco, approved the change of its name to LYNCH COMMUNICATION SYSTEMS INC.

In his remarks to stockholders, President D. E. Campbell stated that while the telephone business will continue to be the mainstay of the Company, expansion into the field of communication systems, including remote control and telemetering systems, is the inevitable result of the Company's research and development program.

The importance of this development to the Lynch Company from a market standpoint is that it can now expand into the electric power, water system, oil and gas pipe line, radio and microwave control, and other fields which have operations that can be benefited by centralization and automation. The existing products of the Company have heretofore confined the major part of its marketing efforts to the telephone communication field.

— *mwj* —

FXR, INC., RETAINS ROBERT D. ECKHOUSE AS PUBLIC RELATIONS CONSULTANT

FXR, Inc., Woodside, New York, a leading manufacturer of microwave equipment, including test instrumentation, has retained Robert D. Eckhouse & Associates, New York, as public relations counsel, Henry Feldmann, president, announced today. The company also develops and manufactures radar components, high voltage power supplies, high power modulators and other electronic equipment.

— *mwj* —

BOYD NAMED AIRTRON GENERAL MANAGER

William F. Boyd, formerly vice president of International Telephone & Telegraph Co., has been appointed general manager of the Airtron division of Litton Industries in Morris Plains, New Jersey it was announced by Litton Vice President Harry J. Gray, board chairman of Airtron.

Mr. Boyd came to Airtron from the general-managership of ITT's Kellogg Switchboard and Supply division in Chicago, Ill. Previously he had been ITT vice president-operations in charge of engineering and manufacturing of microwave carrier equipment, industrial controls, telephone headsets and central office equipment. During his career with ITT Mr. Boyd also had been assistant to the president of the corporation and assistant to the president of ITT Laboratories.

The Airtron division of Litton is major designer and manufacturer of microwave components with New Jersey plants at Linden and Morris Plains and a West Coast plant at Los Angeles.

— *mwj* —

Microwave Component News
from SYLVANIA

Lower relay equipment operating costs with new Sylvania Klystrons

Metallurgical and processing improvements mean superior life and performance

Sylvania's research and production capabilities have produced a series of klystrons that promise to surpass earlier types in performance.

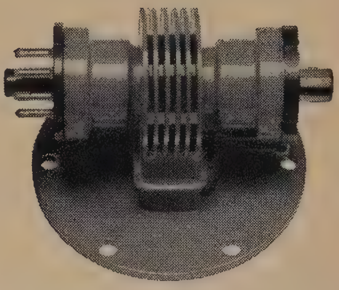
Sylvania's klystrons have the following features:

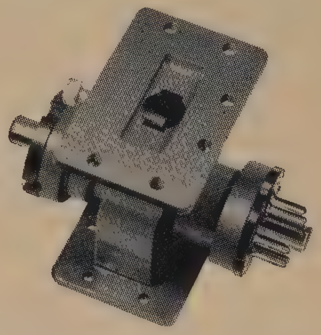
Improved high-temperature glass seal – this permits higher bake-out temperatures and gives a lower gas level. The resulting tubes have a life expectancy of 10,000 hours, 2,000 hours longer than competitive types, and better shelf life. This means lower operating costs for relay link equipment.

Purer metals and materials – the premium quality metals used in these tubes, combined with new, exacting processing techniques permit higher bake-out temperatures and result in longer trouble-free operation with low gas levels.

Superior performance – full coverage from 5925 to 8100 mc with 1 watt nominal output power. Most of these tubes have a minimum electronic bandwidth of 28 mc.

Sylvania klystrons will give you added cost savings because of their longer life and fewer early-life failures. Send for the data.


K-4160, shown approx. ⅓ actual size.
Fins facilitate forced-air cooling.


K-4186, shown approx. ½ actual size.
Flange connects to heat sink.

Forced air cooled	Conduction cooled	Frequency
K-4035	K-4189	5925-6225 mc
K-4162	K-4188	6125-6425 mc
K-4202	K-4187	6425-6575 mc
K-4161	K-4186	6575-6875 mc
K-4034	K-4185	6875-7125 mc
K-4160	K-4184	7125-7425 mc
K-4033	K-4183	7425-7750 mc
K-4036	K-4182	7750-8100 mc

SYLVANIA
Subsidiary of GENERAL TELEPHONE & ELECTRONICS

Sylvania Electric Products Inc.
Special Tube Operations
500 Evelyn Ave., Mountain View, Calif.

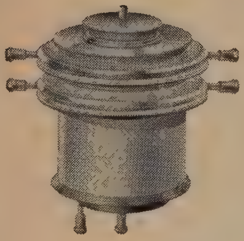
Circle Reader Service Card 33

NEW HARD TUBES FROM CENTRAL FOR POWER HANDLING TO 45 MEGAWATTS

This new line of hard tubes from *Central* is designed for the new higher power Radar installations. These "electrical giants" handle power ranges that previously required many tubes in parallel.

- DIODES for rectifier, clipper and charging service.
- TRIODES for switch tube drivers and switch tube service.
- TETRODES for switch tube service.

Central makes a full line of such tubes along with other microwave components such as TR tubes, gas noise source tubes, and wave guide windows.



XD-32

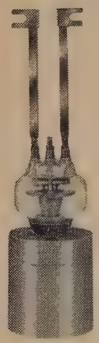
Tetrode Switch Tube

Peak Power	45 megawatts
Plate Voltage	65 KV
Peak Plate Current	750 Amps
Peak Cathode Current	1000 Amps
Duty	.01
Pulse Width	25 μ secs.
Availability	mid 1960

XD-45

Triode Pulsed Switch Tube

Peak Power	3 megawatts
Max. Inv. Plate Voltage	25 KV
Peak Plate Current	120 Amps
Duty	.06
Pulse Width	3000 μ secs.
Availability	immediate



XD-18

High Vacuum Diode

As Rectifier:

Max. Peak Inv. Voltage	40 KV
Av. Plate Current	15 Amps

As Clipper:

Peak Plate Current	300 Amps

Write for Bulletin 2240 for information on all *Central* products. *Central* welcomes your inquiries on new tube designs for advanced applications.

NUCLEAR
CORPORATION
OF
AMERICA

NUCOR

CENTRAL ELECTRONIC MANUFACTURERS
A Division of Nuclear Corporation of America
Denville, New Jersey
Export Department: 431 Fifth Ave., N.Y.C.

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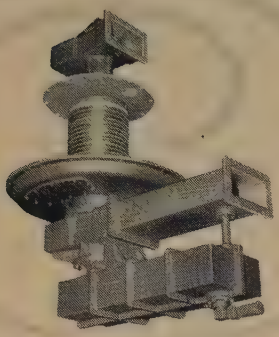
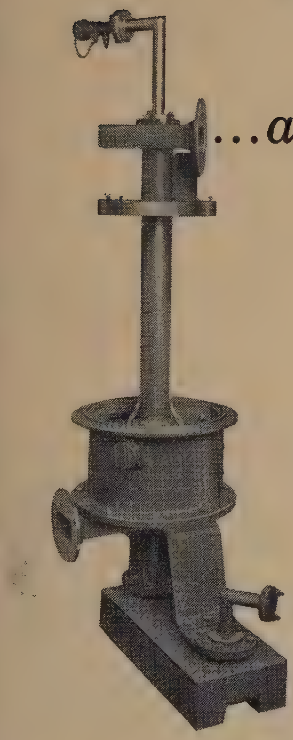
PLAN TO VISIT OUR BOOTH
(1720-1722) AT THE IRE SHOW
March 21st to 24th



LOW VSWR • HI POWER
• NEGLIGIBLE INSERTION LOSS & WOW •

ROTARY JOINTS

...another line of quality Gābriel products



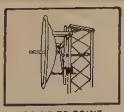
In broad band systems requiring a high degree of circularity (WOW), hi power and negligible insertion loss . . . Gabriel designed and manufactured **ROTARY JOINTS** are a must - - -. Fifteen years of specialized research and development in the field of R-F transmission lines have established Gabriel's supremacy in an industry requiring highly specialized **ROTARY JOINTS**. Complete coupling systems composed of waveguide bends, twists, directional couplers, tuners and rotary joints, feeds, horns and antennas - - - are Gabriel capabilities. Even the more complex components such as dual and triple channel rotary joints . . . coaxial or waveguide . . . capacitive or inductive coupling . . . door knob or probe type transitions are standards in the Gabriel line of fine products. Weatherized, pressurized, ruggedized . . . designed for continuous 25,000 hours operation, without overhaul . . . no rubbing fingers or surface contacts for R-F coupling, the rotary joints are self contained, plug-in types with easy access to service areas. Gabriel's full line of **ROTARY JOINTS** and other R-F transmission line components designed and manufactured in a completely integrated modern 75,000 square foot facility by competent design and manufacturing engineers complement Gabriel's complete antenna system program.

ANTENNA ENGINEERS

Investigate new opportunities for employment at new modern facilities. Expansion offers interesting positions

. . . Call Millis, Mass. — FRontier 6-2953 or write to: Mr. Charles Carlson, Director of Personnel.

Gābriel electronics DIVISION OF THE GABRIEL CO., **MILLIS, MASS.**



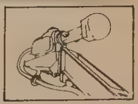
POINT-TO-POINT COMMUNICATION ANTENNAS

ROTARY JOINTS

AIRPORT SURVEILLANCE RADAR ANTENNAS

DRONE & DRONE CONTROL ANTENNAS

RESEARCH & DEVELOPMENT

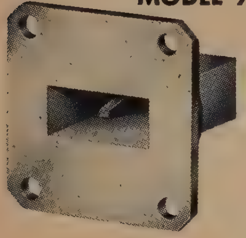


FEEDS AND HORNS

Circle Reader Service Card 35

BOGART

MODEL X4068



MODEL X4069

4068
4069
MICROWAVE
MINI-LOADS

Mini-Loads Series
100 to 150 Watts Average Power

To meet the needs of industry and the Armed Forces, the Bogart Manufacturing Corporation has developed a series of small, lightweight, lossy terminations. For many years resistive wedges, composition strips, and resistance cards, have been used to absorb power in the range from milliwatts up to medium powers. These devices have been extremely fragile, severely limited in heat absorption, subject to moisture absorption, and have exhibited inability to meet standard military shock and vibration specifications. Now, Bogart Manufacturing Corporation has perfected a technique of molding small sections of the **VHP** material that is used in their **4063** series of Government approved high power dummy loads. These **MINI-LOADS** are available in two series; one as an encased dummy load, and the other as a lossy wedge which may be simply inserted into a section of waveguide by the user to meet his particular requirements. In this latter fashion, the **MINI-LOAD** is easily affixed in the same manner as a resistive element; i.e.—cemented into place.

By utilizing the **VHP** material for these **MINI-LOADS,** Bogart Manufacturing Corporation now offers to industry a small termination that is extremely rugged, unbreakable for all practical purposes, and able to take higher powers than any other materials of its size. These **MINI-LOADS** will meet all shock, vibration and humidity requirements of MIL-T-945A, MIL-E-5400A and MIL-E-5272A.

MODEL
WR 4073-18

4073
VHP*
LIQUID COOLED
WAVEGUIDE
DRY DUMMY LOAD

MODEL 4073 SERIES
250,000 to 600,000 Watts Average Power

The Bogart Model 4073 Series of VHP Waveguide Dry Dummy Loads utilizes liquid cooling for absorption of heat. Unlike conventional **water loads,** which depend on the liquid for electrical attenuation properties as well as for heat transfer properties, the 4073 series utilizing the Bogart patented VHP lossy material has independent electrical and thermal characteristics. This permits optimum electrical design based on the characteristics of the lossy material, while cooling is handled separately by external means.

The Bogart liquid-cooled dry loads are much preferred by engineers to the old-time **pure water loads,** for a variety of reasons. The 4073 units may be oriented in any position either for test work or for permanent mounting in the system. The electrical characteristics of these units remain **constant** and independent of water temperature from near freezing to near steam.

The electrical characteristics of pure water loads will vary with almost any variations in water temperature necessitating a complex and costly heat exchanger and pumping facility. The pure water load requires an extremely accurate control on water pressure to absorb energy without destroying the vane which is commonly used, and to avoid harmful bubbles in the water jet.

The 4073 Series can withstand wide variations in water pressure, often as much as 50%, permitting the use of an inexpensive pumping facility. In addition, these Bogart loads can, in many cases, be run **dry** without any liquid cooling for considerable periods of time. Despite all advantages of these liquid-cooled dry loads, their cost is no higher than that of pure water loads. The savings in accessory equipment permit engineers to obtain all advantages of a **liquid-cooled dry load** and still spend less on their overall dummy load installation.

*PATENT PENDING

BOGART

BOGART MANUFACTURING CORP.
serving the electronics industry since 1942 design • development • production
315 Seigel Street Brooklyn 6, New York

Circle Reader Service Card 36

INDUSTRY NEWS

GE NAMES NEW SYSTEMS DESIGN MANAGER

Peter G. Smee has been appointed manager of Microwave Systems Design fo General Electric's Communication Product Department at Lynchburg, Va. The appointment was announced by I. T. Corbell the department's manager of Microwav Engineering.

Smee is a native of Lincoln, England an received his technical training in the Unite Kingdom. He holds several U. S. patent in the communication field. He joine General Electric at Electronics Park, Syracuse, N.Y.. in 1946 and specialized in microwave engineering for the past severa years.

He is a Senior Member of the Institut of Radio Engineers.

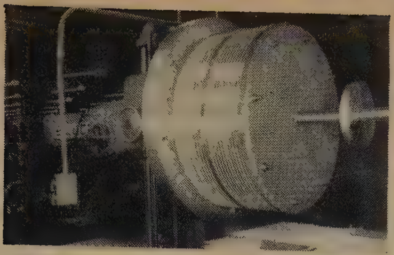
— *mwj* —

AIRBORNE INSTRUMENTS LABORATORY NAMES TOP RESEARCH AND ENGINEERING OFFICERS

E. G. Fubini

Airborne Instruments Laboratory (AIL), Deer Park, N. Y., yesterday announced th appointments of Dr. E. G. Fubini and D G. C. Comstock as vice presidents. D Fubini and Dr. Comstock formerly wer co-directors of AIL's Research and Engineering Division. AIL is a division c Cutler-Hammer, Inc.

(*Continued on page 50*)



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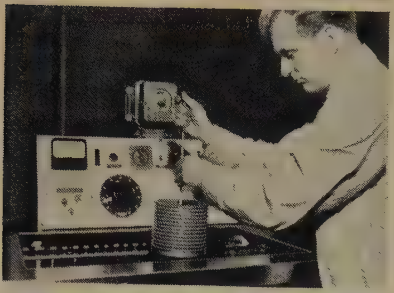
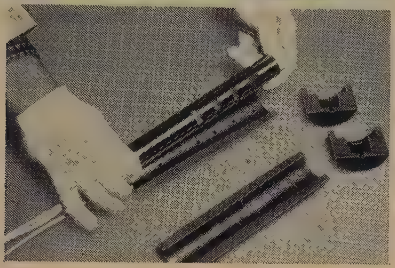


ELECTRO-PLATED



MOLDED

No Compromise

IN THE DESIGN OR PRODUCTION OF
CUSTOM SLIP RING ASSEMBLIES...

. . . at Breeze. With the depth of design and production capabilities and facilities at Breeze Corporations, your slip ring requirements are met without compromise. Breeze produces custom slip ring assemblies by *all* of the reliable methods and techniques, thus assuring you of a unit tailored to meet your unique requirement.

Let Breeze provide you with an uncompromised design and production analysis before you buy.

You'll want a copy of the new Breeze catalog 66SR which describes a wide range of custom units as well as Breeze standard slip ring assemblies.

BREEZE
MARK

BREEZE CORPORATIONS, INC.
700 Liberty Avenue, Union, New Jersey • Telephone: MUrdock 6-4000

Manufacturers of electrical, electro-mechanical and hydro-mechanical components and systems and fabricated metal products.

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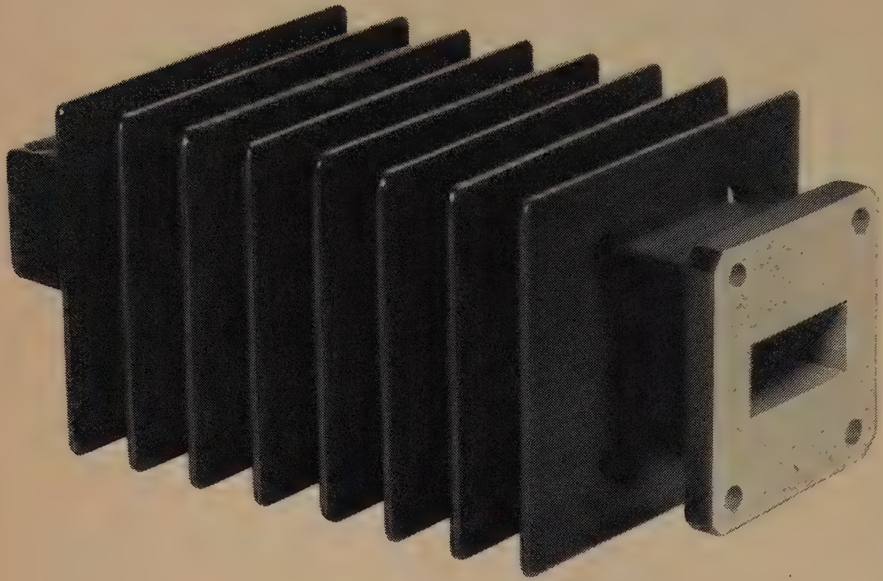
DISSIPATING



DUMMY

Jush look at me, I'm a dishipating dummy. Boy, can I carry a load! I'm part of Airtron's fambly of high power dummy loads. Small and light, we're capabubble of dishipating very high power radar outputs.

* * *

Silicon Carbide is the absorbtive element.

The new series covers the frequency spectrum from L to Ka band, 1.12 to 40.0 Kmc/s. Each model is designed to be pressurized and meets requirements of MIL-D-3954A. Here are the specifications for this new series:

FREQ. RANGE (KMC/S)	MINIMUM AV. POWER (WATTS)	MAX. PEAK POWER (MEGAWATTS)
1.12- 1.70	8000	17.2
2.60- 3.95	4500	3.2
3.95- 5.85	2000	2.0
5.85- 8.20	1000	0.71
7.05-10	600	0.46

FREQ. RANGE (KMC/S)	MINIMUM AV. POWER (WATTS)	MAX. PEAK POWER (MEGAWATTS)
8.2 -12.4	500	0.29
12.4 -18.0	250	0.16
18.0 -26.5	150	0.125
26.5 -40.0	75	0.075

For additional information on Airtron's dummy loads or other microwave components, write or call . . .

AIRTRON
A DIVISION OF LITTON INDUSTRIES

PACIFIC COAST FACILITY: 5873 RODEO ROAD, LOS ANGELES 16, CALIFORNIA

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Dr. Fubini was named vice president in charge of Research and Systems Engineering and Dr. Comstock, vice president in charge of the Electronic Systems and Techniques Division. Both of these divisions are newly created divisions within AIL.

— *mwj* —

RANTEC APPOINTS SINGER NEW MARKETING DIRECTOR

George Singer, formerly general manage of the Microwave Division of Kearfot Company, Inc., has been named Directo of Marketing and Contracts for the Rante Corporation of Calabasas, California, according to Rantec president Robert Krausz

Prior to his position as head of Kearfott's Microwave Division, Singer was general manager of their Western Division responsible for marketing in the wester states.

Singer has previously held engineerin positions with Boeing Airplane Compan and Standard Oil Company, New Jersey.

Rantec produces a variety of microwav products including antennas, telemetering multiplexers, waveguide switches, ferrit devices, stripline components and othe waveguide components. Recent developmen contracts have included essential items fo several major space programs.

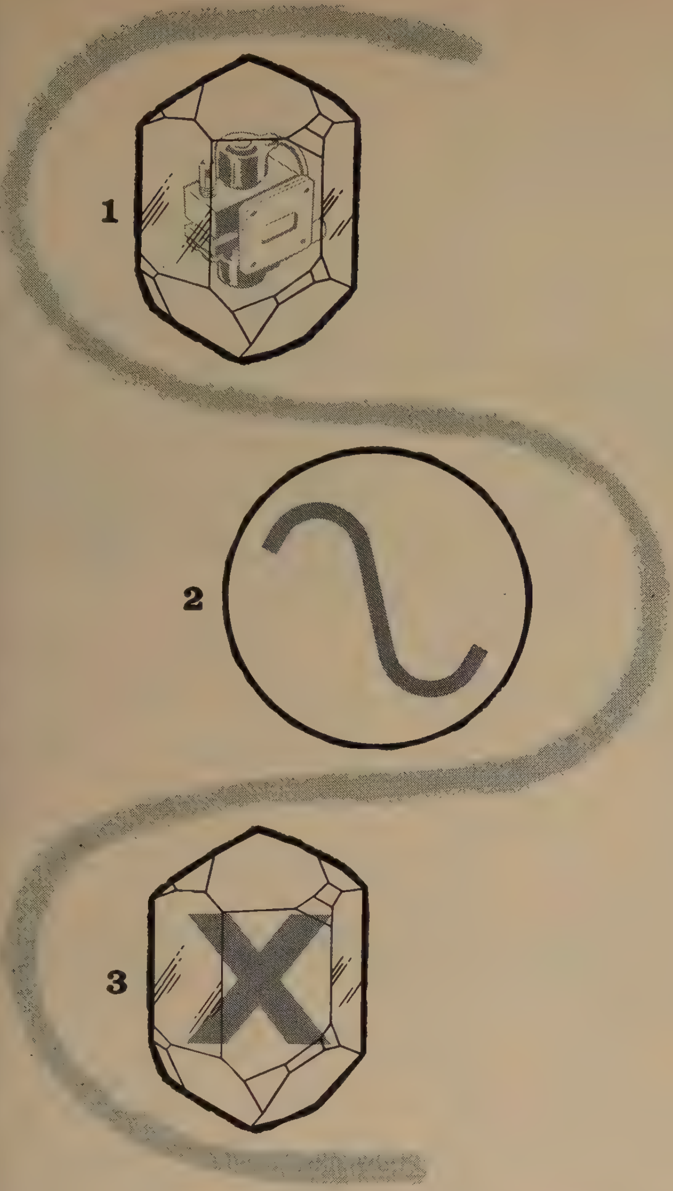
— *mwj* —

RAMAGE & MILLER ACQUIRE WAVE PARTICLE

Ramage & Miller, Inc., of Richmond California, has recently acquired th Wave Particle Corporation of Menl Park, California, and has moved the entire facility to their main plant in Richmond, where it is being operated as th Wave Particle Division of Ramage & Miller, Inc.

This new Wave Particle Division wi be principally devoted to the manufacturing of Traveling Wave Tube Amplifie and Backward Wave Oscillators. A R & D Program now in progress is devoted to developing a complete new lin

(*Continued on page 52*)



3 approaches to MICROWAVE STABILITY

3 different "state-of-the-art" approaches for achieving microwave frequency stability are utilized in the LFE Oscillators described below. Each of these instruments exemplifies LFE's leadership in this specialized field — each will be demonstrated at the 1960 IRE Show, Booths 3819-21.

	1 Crystal-Locked Klystron Approach	**2** Dual Mode Reference Cavity Approach	**3** Crystal Multiplier Approach
LFE MODELS	Series 820-XLK Crystal-Locked Klystron Source	Series 814 Ultra-Stable Microwave Oscillator	Model 5010 S-Band Exciter
FREQUENCY RANGE	S-band to K-band fixed frequency	27 tunable models covering 2.5 mc —27Kmc	S-band fixed frequency
POWER	Approx. full klystron power	Up to 500 mw @ X-band or 1.5 w @ C-band	125 mw
SHORT-TERM STABILITY	1 part in 10^8	5 parts in 10^8	1.2 cps (incidental FM)
LONG-TERM STABILITY	1 part in 10^6 (24-hour period) Generally independent of environmental conditions	1 part in 10^6	Less than 100 kc drift over 25-hr. period

Write for complete specifications.

LFE

LABORATORY FOR ELECTRONICS, INC. **BOSTON, MASS.**

Instrument Division **714 BEACON STREET**

WESTERN REGIONAL OFFICE, 211 South Beverly Drive, Beverly Hills, California, CRestview 5-5327

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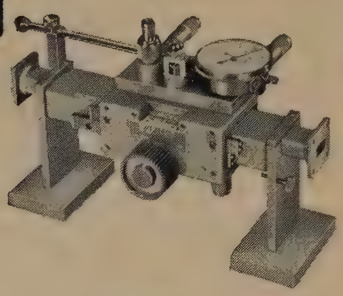
precision measurement demands

WAVELINE MICROWAVE

instruments

ATTENUATORS
SLOTTED LINES
WAVEGUIDE COUPLERS
TERMINATIONS
FREQUENCY METERS
PHASE SHIFTERS
DETECTOR MOUNTS
PRECISION TUNERS



and components

MIXERS
FILTERS
ANTENNAS
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DIRECTIONAL COUPLERS
WAVEGUIDE TEES
DETECTOR MOUNTS
WAVEGUIDE SWITCHES

The ninety page Waveline catalog describing over 600 instruments, includes complete technical data, charts, illustrations and engineering reports.

WAVELINE INC.
CALDWELL, NEW JERSEY

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(Continued from page 50)

of Microwave Signal Sources using Backward Wave Oscillators which will feature wide frequency coverage, high power output and low noise. A prominent aspect of this new line will be their modern design, small size and light weight.

Ramage & Miller, Inc., formerly Ramage & Miller Enterprises, was established early in 1956 to manufacture specialized products, including Weather Radar Systems, Radar Target Augmenters, Magnetron Modulators and Power Supplies.

MILLER

CLINTSMAN

Mr. Frank A. Miller, President of Ramage & Miller, Inc., was formerly a co-owner of Ramage & Miller Enterprises, prior to which time he was employed with the Systems Division of Beckman Instruments. He received his formal education in Electronics at California State Polytechnic College and received Post-Graduate Training in Microwave techniques at the University of California.

Secretary-Treasurer of Ramage & Miller, Inc., is Mr. Bert F. Clintsman, who was the former Office Manager & Comptroller of Ramage & Miller Enterprises. For eleven years previously, he was Field Engineer and Sales Representative in the eight Western States for The Hickok Electrical Instrument Co. Mr. Clintsman is widely known for his work in the control field and also as the former owner of Bert Clintsman Co., a precision instrument laboratory operating on the Pacific Coast for the past sixteen years. He is now Production Manager of the new Wave Particle Division.

— *mwj* —

HANSEN SUCCEEDS JASIK ON MICROWAVE JOURNAL BOARD

Robert C. Hansen, Senior Staff Engineer in the Telecommunications Laboratory of Space Technology Laboratories, Inc., has been named Associate Editor of *the microwave journal* according to a recent announcement by William Bazzy, publisher of *the microwave journal*, and Theodore S. Saad, the book's Technical Editor.

Dr. Hansen succeeds Dr. Henry Jasik who is currently engaged in compiling an antenna engineering handbook. Dr. Jasik has agreed to act in an Associate capacity until he is able to participate more actively.

Dr. Hansen, born in St. Louis, Missouri in 1926, attended the Missouri School of Mines and Metallurgy until his education

(Continued on page 54)

Circle Reader Service Card 40

LEADS THE INDUSTRY IN ULTRA-HIGH-POWER DUPLEXING

with both GAS DISCHARGE and FERRITE DUPLEXERS

Selecting a duplexer for high-power applications involves consideration of peak power, average power, transmit loss, receive loss, expected life, and versatility of operation.

All Microwave Associates high power gas duplexers utilize special window structures for optimum switching efficiency without sacrifice in low-level loss characteristics. These windows insure reliable, long-life performance. Both our gas and ferrite duplexers may be operated over very broad bandwidths at the common microwave frequencies.

Exceptionally complete ultra-high-power design and test equipment is utilized by our Research and Production Departments. Each duplexer is fully tested at maximum rated power before shipment.

We have extensive experience in designing and manufacturing high-power duplexer devices and are interested in working on newest ultra-high-power applications. We are now developing ultra-high-power duplexers for more efficient switching at UHF, L, C, and S bands.

Our Applications Engineers would like to discuss the future of high power duplexing with you.

Frequency Band	Duplexer Type	Peak Power	Average Power	Transmit Loss (max.)	*Receive Loss (max.)	Bandwidth
UHF	Gas	5 Mw	300 Kw	0.1 db	0.4 db	Tunable
	Gas	25 Mw	75 Kw	0.1 db	0.4 db	10% Nominal
L	Gas	25 Mw	50 Kw	0.1 db	0.5 db	
S	Gas	6 Mw	30 Kw	0.1 db	0.7 db	
	Ferrite	3 Mw	5 Kw	0.5 db	0.9 db	
C	Gas	5 Mw	5 Kw	0.1 db	0.7 db	
	Ferrite	5 Mw	7.5 Kw	0.3 db	0.8 db	
X	Gas	500 Kw	500 W	0.2 db	1.0 db	
	Ferrite	1 Mw	1 Kw	0.3 db	0.9 db	
Ku	Gas	150 Kw	150 W	0.2 db	1.0 db	
	Ferrite	150 Kw	150 W	0.3 db	0.9 db	
Ka	Ferrite	75 Kw	75 W	0.3 db	1.1 db	4% Nominal

All Microwave Associates duplexers incorporate low-loss, long-life, receiver protectors which guarantee crystal protection over wide temperature ranges and under extreme environmental conditions.

*The duplexer receiver loss includes the loss due to receiver protector TR tubes.

Visit us at IRE Show, Booth 2301 - 2303

At each frequency band of the microwave spectrum, Microwave Associates has devices for efficient switching of high power.

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the leader and pioneer in stalos

STALO STABILITY TESTER

Accurate to 1 part in 10^9

A VERSATILE MICROWAVE STABILITY TESTER... DESIGNED FOR ANY APPLICATION REQUIRING PRECISE MEASUREMENT OF FREQUENCY STABILITY.

On Demonstration at Booth 3024, IRE Show

SERIES 800

Measures long term drift and short term deviation in frequency bands from UHF to 10,000 mc. Checks stability of radar systems components such as stalos, cohos, klystrons and other stable signal sources – either on the production line or in the field. Particularly useful in the design, testing and maintenance of MTI equipped radars.

FEATURES:

- Short Term Accuracy: 1 part in 10^9
- Long Term Accuracy: 1 part in 10^6
- Provision for Disturbance Frequency Spectrum Analysis
- Direct Meter Presentation of Frequency Drift and Deviation
- Full MIL Construction and Reliability

. . . and moderately priced!

Other PITLOG components – **Tunable Stalos**
Self-contained stable local oscillators used as references for determining the phase or frequency shift of a radar echo. Offer high order of short term stability and high power output.

UHF Tunable Stalo
Frequency Range....300-600 mc
Tuning Range..................10% +
Stability....less than 5 cps peak

L-Band Tunable Stalo
Frequency Range 1000-1500 mc
Tuning Range...............10% +
Stability................4-8 cps peak

S-Band Tunable Stalo
Frequency Range 2000-3200 mc
Tuning Range...............10% +
Stability..............7-10 cps peak

Write for Bulletin M-4

PITLOG

PITOMETER LOG CORP.
237 Lafayette Street New York 12, N. Y.
Advanced Instrumentation Since 1927

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Industry News

(*Continued from page 52*)

was interrupted for a tour of service in the U.S. Navy in 1944. He was an honor student at the School of Mines and received a B.S. in EE degree. The M.S. and Ph.D. degrees were obtained from the University of Illinois in 1950 and 1955.

While there, he worked in the Antenna Laboratory on ferrite loops and streamlined airborne antennas. Subsequently he became Senior Staff Engineer in the Microwave Laboratory of Hughes Aircraft Company working on surface wave antennas, slot arrays, and near fields. Since that time, he has been with Space Technology Laboratories.

Dr. Hansen is a member of the Institute of Radio Engineers, the American Physical Society, *Tau Beta Pi, Sigma Xi, Eta Kappa Nu, Phi Kappa Phi,* and Commission VI of URSI.

In 1957, he was Professional Group coordinator for the Los Angeles Section of IRE and was Co-chairman of the Papers Committee, 1957 RTCA-IRE Symposium. He is a member of the IRE Antennas and Waveguide Committee, the PGAP and PGMTT Administrative Committees, and is Western Vice-Chairman of the IRE Professional Groups Committee.

Dr. Hansen has written a number of technical reports and papers.

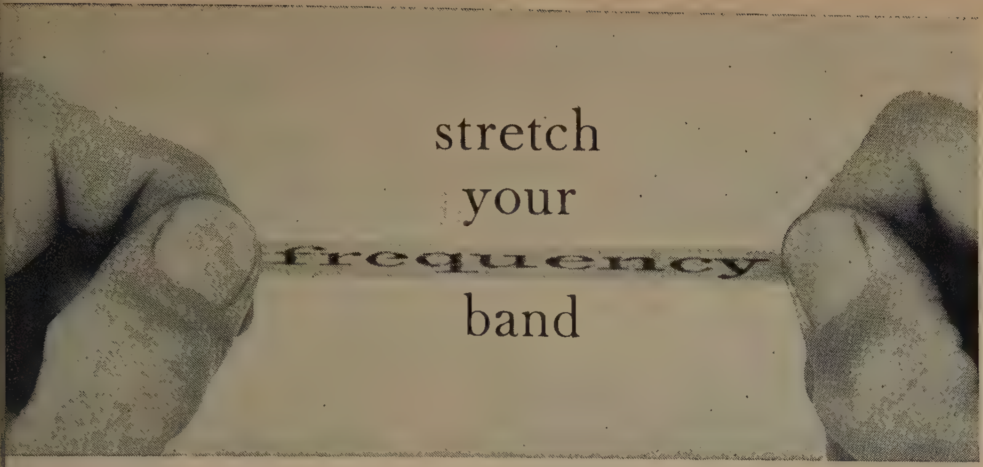
— *m w j* —

GORHAM ACQUIRES PICKARD & BURNS

The Boards of Directors of Gorham Manufacturing Company, one of Rhode Island's leading manufacturing concerns, and Pickard & Burns, Inc. of Needham, Massachusetts, well-known engineering specialists in research, development and production of electronic apparatus, systems and components, have approved terms of the acquisition by Gorham of all of the assets of Pickard & Burns. This announcement was made jointly by Wilbur H. Norton, President of Gorham Manufacturing Company, and Harold S. Burns, President of Pickard & Burns.

The business of Pickard & Burns will be operated as a wholly-owned subsidiary corporation with Harold S. Burns Presi-

(*Continued on page 56*)

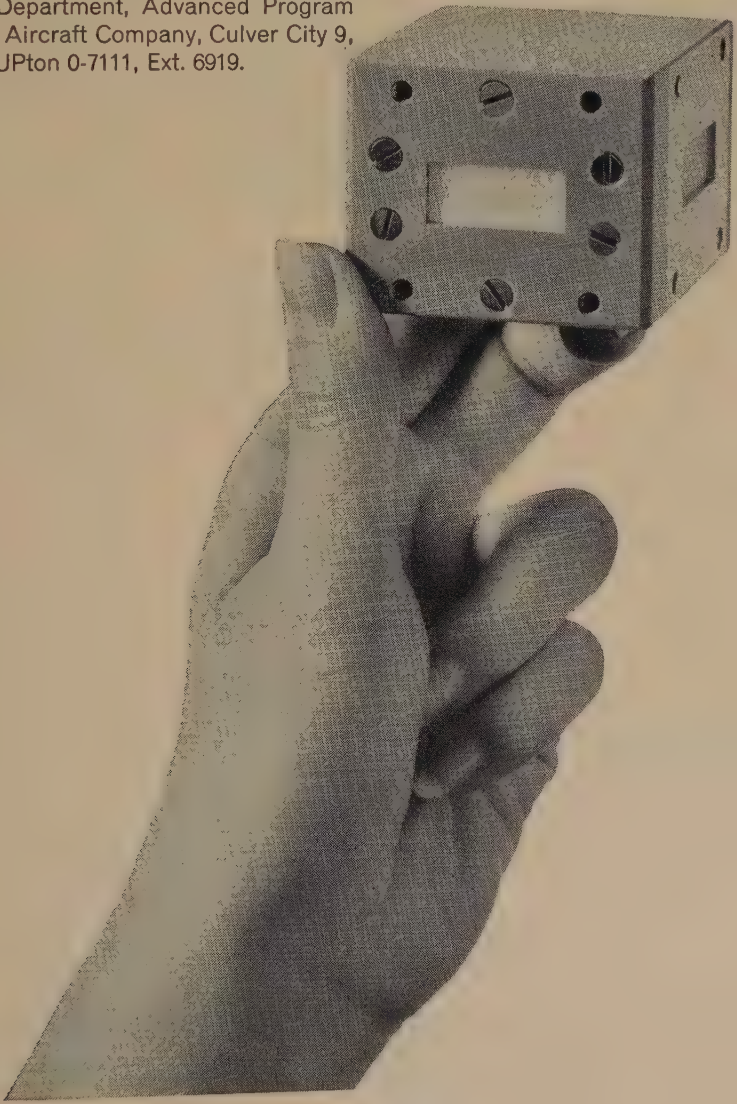


with new Hughes "20-20" Circulators!

With 20% bandwidth and over 20 db isolation, the new Hughes "Y" and "T" Circulators are ideally suited for microwave reception and transmission applications. They also give you small size and weight...without sacrifice in performance. C- and X-Band models are available today!

For information on the new "20-20" Circulators, or other advanced microwave components, please write Microwave Products Department, Advanced Program Development, Hughes Aircraft Company, Culver City 9, California. Or, phone UPton 0-7111, Ext. 6919.

	Model C-201A	Model X-230A (Illustrated)
Frequency:	4.9-6.2 Kmc	8.0-9.8 Kmc
Isolation:	20 db	20 db
Insertion Loss:	0.3 db	0.3 db
Input VSWR:	1.10	1.20
Power Capacity:	10 Kw peak 100W avg (Min.)	3 Kw peak 50W avg (Min.)



ALSO AVAILABLE: Miniaturized S- and L- Band Coaxial Circulators. New, extremely small (1" x 2" x 8") circulators with bandwidths to 10%, over 20 db isolation, and 0.5 db insertion loss are now available.

Creating a new world with ELECTRONICS

HUGHES

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MICROWAVE PRODUCTS

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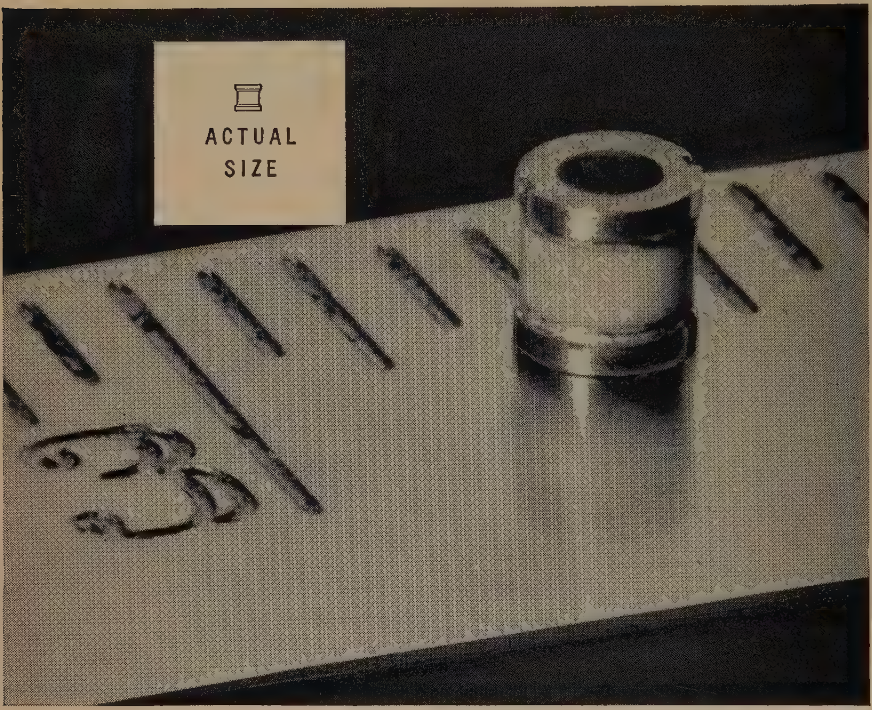
NEW SILICON
"PILL" VARACTOR



GREATLY REDUCES THE PACKAGE
AS A FACTOR IN CIRCUIT DESIGN

specifically developed for:

- amplifiers at the higher microwave frequencies (1000 mc and above)
- travelling wave parametric amplifiers
- microwave computers as sub-harmonic generators
- amplifiers in which stray susceptance effects must be minimized
- applications of varactors to stripline circuits
- modulators for frequency synthesis

Experimental quantities are available with these nominal specifications

TYPE NUMBER	*CAPACITANCE TOLERANCE (Zero Bias)	TYPICAL Q AT −6 VOLTS
MA-4255X	0.1-1.4 $\mu\mu f$	60-80
MA-4256X	1.2-2.5 $\mu\mu f$	50
MA-4257X	2.5-4.0 $\mu\mu f$	30

*Package shunt capacitance ~ 0.2 $\mu\mu f$. Series lead inductance $<10^{-9}$ henries.

Write or call:
MICROWAVE ASSOCIATES INC.
BURLINGTON, MASSACHUSETTS
BRowning 2-3000 • TWX Burlington, Mass. 942.

Circle Reader Service Card 44

Industry News

(*Continued from page 54*)

dent and current officers continuing. Mr Burns, in addition to serving as Presiden of the subsidiary, Pickard & Burns, wil assume general management of Gorham' Electronics Division, thereby providin effective coordination of these two organizations.

The management of both companie believe that substantial benefits will accrue as a result of this merging of tw active electronic organizations. In recen months, as a part of its diversificatio program, Gorham has begun to enlarg its electronic capabilities by the establishment of an engineering and research and development group within its Electronic Division. The acquisition of Pickard & Burns will result in a valuable increase in research and development facilities, both in the field of military contracting and the development of new proprietary electronic products.

LITERATURE . . .

COPPER FURNACE BRAZING HANDBOOK

"Design for Controlled Atmosphere Copper Furnace Brazing — a Handbook fo Designers, Engineers, and Manufacturers' is a technical handbook just published b Fabriform Metal Products, Los Angele brazing specialists. Profusely illustrated the 24-page book incorporates the lates technical information on copper furnac brazing, a metal-joining process that is o increasing importance in many industries including aviation and missiles and electronics.

Included are chapters on what the brazing process is, where brazing is used, "do' and dont's" for designers, inspection methods, and charts and tables of engineering data.

Circle Reader Service Card 101

— *m w j* —

GENERAL BRONZE CORPORATION RELEASES PAPER ON TELEMETRY ANTENNA SYSTEM

The Research Publications office of General Bronze Corporations Electronics Division at Valley Stream, New York, announced today that a New Paper on Telemetry Antenna Systems is now available.

This Paper, entitled: "A New Departur In Telemetry Antenna Systems" by Joh P. Parry, special projects engineer, explain in detail the specific configurations, specifications and applications of certain of th General Bronze SVE Antenna Developments.

Reprints of this Paper originally presented at the Maecon Conference in Kansa City, Mo., will be sent free of charge upo request as long as supplies last.

Circle Reader Service Card 102

— *m w j* —

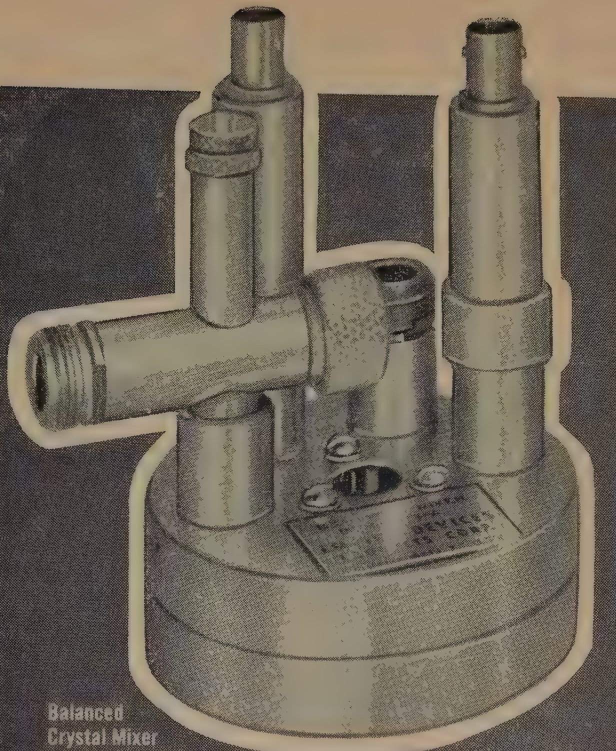
REXOLITE 2200 DATA SHEET

A full-color, single-sheet data page, discussing electrical, chemical and physica properties of Rexolite 2200, now is availabl from Rex Corporation, West Acton, Mas

(*Continued on page 58*)

The Most Complete Line of

COAXIAL BROADBAND CRYSTAL MIXERS



Balanced
Crystal Mixer
Model BCM-107E
2500-2900 MC.

BALANCED MIXERS, Model BCM-107

For R.F. frequencies from 1000 to 5600 MC.
Models for push-pull or single-ended I.F. inputs.
Featuring, over a 15% bandwidth:

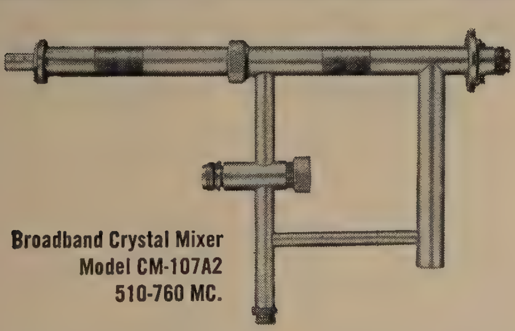
- ★ Input VSWR less than 1.5 to 1, without adjustment.
- ★ L.O. noise cancellation at least 20 DB.
- ★ Isolation between R.F. and L.O. at least 20 DB.
- ★ L.O. rejection at I.F. terminals at least 30 DB.

We have the answers to many unique coaxial mixer design requirements.

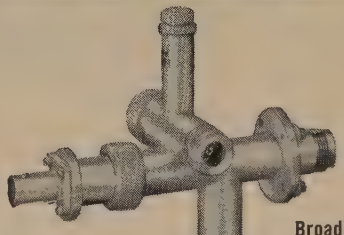
• Broadbanding • Low VSWR • Unusual Frequency Combinations • Low-Noise Design • R.F.-L.O.-I.F. Isolation.

The expanded line of coaxial mixers from EMPIRE represents the solution to these, and many other problems. Most types are available for immediate delivery from stock.

WHAT IS YOUR SPECIAL PROBLEM?



Broadband Crystal Mixer
Model CM-107A2
510-760 MC.



Broadband Crystal Mixer
Model CM-107F
4000-5600 MC.

BROADBAND MIXERS, Model CM-107

For R.F. frequencies from 225 MC to 8200 MC.
Featuring over a broad range of frequencies:

- ★ Input VSWR less than 2 to 1, without adjustment.
- ★ L.O. VSWR less than 2 to 1, without adjustment.
- ★ L.O. rejection at I.F. output, better than 30 DB.
- ★ L.O. power requirements 10 MW, with adjustable injection feature.

For complete data, send for Catalog 604.

edp

EMPIRE DEVICES PRODUCTS CORP.
AMSTERDAM, NEW YORK
VICTOR 2-8400

MANUFACTURERS OF:
FIELD INTENSITY METERS • DISTORTION ANALYZERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS • CRYSTAL MIXERS
VISIT OUR BOOTHS 3818-20 AT THE IRE SHOW

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FULL OCTAVE
S-BAND
RANGE
2.1 KMC
TO
4.3 KMC

MICROWAVE Kearfott PRODUCTS

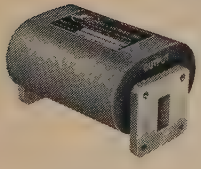
FERRITE ISOLATOR

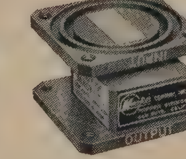
The all new Model WD-2106 Octave S-Band Isolator marks a revolutionary advancement in the microwave field by permitting the use of only one isolator for a full octave frequency range instead of covering the band in increments using a number of isolators. Ideal for use in telemetry, radar systems and transponders, the new unit offers exceptional reliability, excellent isolation to insertion loss characteristics and compactness of design.

TYPICAL SPECIFICATIONS

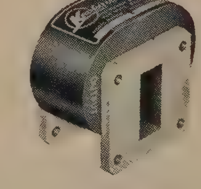
MODEL	FREQ. RANGE	ISOLATION	INSERTION LOSS	V.S.W.R.
WD-2106	**2.1-4.3 KMC**	**20 DB Min.**	**2.0 DB Max.**	**1.5 Max.**
W-568-3A-2	12.5-18.0 KMC	20 DB Min.	1.0 DB Max.	1.15 Max.
W-177-1K-1	9.5 KMC ± 100 MC	25 DB Min.	.7 DB Max.	1.15 Max.
W-277-3A-3	5.2-5.9 KMC	17 DB Min.	1.0 DB Max.	1.15 Max.
W-668-1A-2	8.5-9.6 KMC	10 DB Min.	0.4 DB Max.	1.10 Max.

THESE ARE ONLY A FEW OF THE MANY AVAILABLE MODELS


W-568-X


W-177-X

W-277-X


W-668-X

KEARFOTT DIVISION

GENERAL PRECISION INC.

14844 OXNARD ST., VAN NUYS, CALIF.

Literature

(*Continued from page 56*)

The sheet includes curves for dissipatio factor, dielectric constant and attenuation o Rexolite 2200, a reinforced thermosettin plastic insulating material designed for us at ultra high and microwave frequencies i both wet and dry locations. It also discusse end uses and availability of the material.

Circle Reader Service Card 103

— *mwj* —

SCHWEBER ELECTRONICS BROCHURE

A specially prepared four-page, tw color brochure has been produced b Schweber Electronics, Mineola, L. I., N. Y which serves as a guide to the selection o RF Connectors by RG Cable types.

It includes a cross reference of Cable versus applicable Connectors to facilitate th selection of Connectors for specific Cable Cable and Connector types listed includ all versions. It also includes a guide fo adapters between series which provide means of connection between various solid dielectric RF Cable Connector Series, a well as category definitions, to indicate current preferences over obsolescent components and their preferred replacement in R transmission line applications.

Circle Reader Service Card 104

— *mwj* —

G.E. ELECTRIC-FURNACE BRAZING BULLETIN

"How And Where To Use Electric Furnace Brazing" — Bulletin GEA-3193 — is a rerelease of an all time "best seller on the subject of electric-furnace brazin compiled several years ago by the Genera Electric Co., Schenectady, New York.

The 50-page illustrated bulletin cover such subjects as the where and why c furnace brazing, how to remove coppe from steel after brazing, application an selection of brazing metal, selection of flux strength of furnace-brazed parts, how t furnace-braze cast iron and remedies fo furnace-brazing ailments.

Circle Reader Service Card 105

— *mwj* —

CONDENSED CATALOG DESCRIBE TELONIC SWEEP GENERATORS AND ACCESSORIES

A new condensed product catalog is no available from Telonic Industries, Inc Beech Grove, Indiana.

The new four-page bulletin, designate as Telonic Catalog 8-B, provides a complet listing of Telonic Industries' standard lin of sweep generators and accessories, including a number of instruments not previously described.

Telonic sweep generators cover the enti frequency range from 1 to 2300 mc., in variety of sweep widths and individual instrument ranges. Features include extreme flat power output, a "Birdy-By-Pass" technique of adding frequency markers, and versatile system of plug-in marker unit Accessories include attenuators and RF detectors for use in measuring systems incorporating the Telonic sweep generators.

Copies of the Bulletin are available c request.

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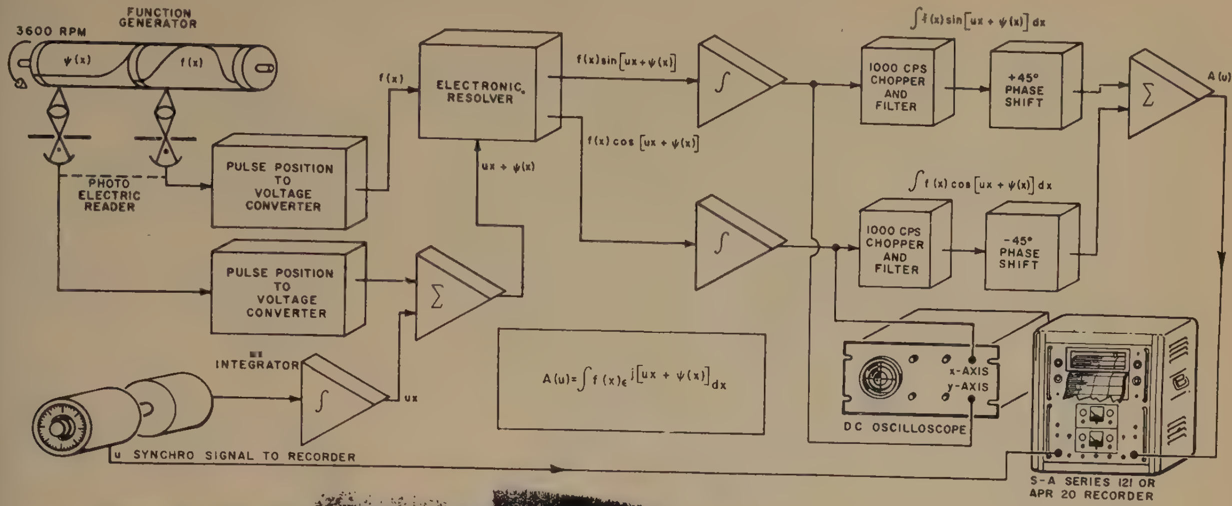
Circle Reader Service Card 46

Simplified block diagram of Model CF-1. Amplitude and phase input functions are plotted on graph paper for presentation. Integration is observed on a dc oscilloscope. Absolute magnitude is recorded on any S-A Series 121 or APR 20 Antenna Pattern Recorder with a logarithmic response.

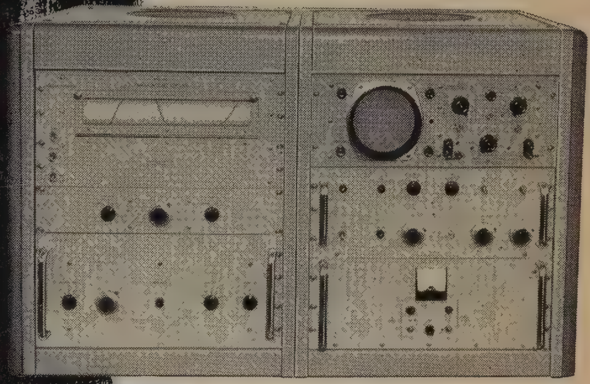

FUNCTION GENERATOR
3600 RPM
ψ(x)
f(x)
PHOTO ELECTRIC READER
PULSE POSITION TO VOLTAGE CONVERTER
PULSE POSITION TO VOLTAGE CONVERTER
f(x)
ELECTRONIC RESOLVER
ux + ψ(x)
f(x) sin [ux + ψ(x)]
f(x) cos [ux + ψ(x)]
∫ f(x) sin [ux + ψ(x)] dx
∫ f(x) cos [ux + ψ(x)] dx
1000 CPS CHOPPER AND FILTER
1000 CPS CHOPPER AND FILTER
+45° PHASE SHIFT
-45° PHASE SHIFT
A(u)
INTEGRATOR
ux
u SYNCHRO SIGNAL TO RECORDER
A(u) = ∫ f(x) ε^j[ux + ψ(x)] dx
X-AXIS
Y-AXIS
DC OSCILLOSCOPE
S-A SERIES 121 OR APR 20 RECORDER

To solve

$$A(u)=\int_{-1}^{1} f(x)\,\epsilon^{j[ux+\psi(x)]}\,dx$$

investigate the new

FOURIER INTEGRAL COMPUTER



Model CF-1

A sophisticated solution to the vexing problem of solving bounded Fourier integrals quickly and accurately, Scientific-Atlanta designed the Model CF-1 especially for the antenna design engineer.

The computer has broad general application including determination of the far fields of aperture antennas from the distribution of the field in the aperture, the far fields of arrays from the magnitude and phase of the currents in the elements, the frequency spectra of voltage pulses, and other physical problems involving Fourier transforms and their inverse transforms over finite limits.

PRICES

Model CF-1 Fourier Integral Computer . . . $9,000

Model APR 22 Antenna Pattern Recorder (logarithmic response) . . . $4,300

See the CF-1 and other new S-A Microwave nstrumentation at IRE Booth 3909

Consult your nearby S-A engineering representative for more information. Or you may write directly to the factory for complete specifications. Address Dept. 68-3.

SCIENTIFIC-ATLANTA, INC.
2162 PIEDMONT ROAD, N.E. • ATLANTA 9, GEORGIA
Tel. TRinity 5-7291

Circle Reader Service Card 47

HIGH TEMPERATURE REINFORCED PLASTIC DESCRIBED IN NEW BULLETIN

TRC-X, a new high strength reinforced phenolic laminate which withstands temperatures in the 1000°F range without blistering or delaminating, is described in an interim bulletin published by Riverside Plastics Corp., Hicksville, New York. The bulletin gives temperature vs time data on flexural strength, flexural modulus, tensile strength and edgewise compression. Information on thermal expansion, thermal conductivity and specific heat is also included.

Copies are available on request.

Circle Reader Service Card 107

— mwj —

NEW CARY MODEL 31 ELECTROMETER BULLETIN

A new four-page bulletin describes the Cary Model 31 Vibrating Reed Electrometer manufactured by Applied Physics Corporation. The Model 31 is used to detect currents as small as 10^{-17} amperes, charges to 6 x 10^{-16} coulombs and voltages to 20 microvolts. Applications include measurement of large resistance values, capacitance, dielectric constants and other electrical properties.

The new bulletin discusses operation, applications, specifications and performance.

Copies are available on request.

Circle Reader Service Card 108

FERRITE COMPONENTS CATALOGUE AVAILABLE FROM CASCADE

Listing over 85 models of microwave ferrite components, a new short form catalog has just been released by Monogram Precision Industries, Inc. — Cascade Research Division, Los Angeles, California.

Believed to be the broadest line of waveguide and coaxial isolators, modulators, circulators, circulator switches, and phase shifters offered to the electronics market, the components shown include the recently introduced small size "Y," "T," and cross-type circulators, one-tenth to one-fifth the size and weight of corresponding conventional circulators.

Circle Reader Service Card 109

— mwj —

WAVEGUIDE DATA CHART AVAILABLE FREE FROM NARDA MICROWAVE

A new "Standard Waveguide Data Chart," one of the most complete listings of waveguide information available today, has been prepared by the Narda Microwave Corporation, Mineola, Long Island, New York. Featuring military as well as EIA designation numbers, the chart shows virtually all required electrical as well as mechanical parameters for all waveguides in use today.

Up to now, engineers have frequently had to devote considerable amounts of time to calculating certain characteristics, attenuation factors, power ratings, etc. The new chart provides the most commonly-used data, eliminating the necessity for calculations. Some of the parameters covered are: cut-off frequency, theoretical attenuation for both brass and aluminum waveguides, theoretical C.W. power rating, and the waveguide wavelength from the lowest to the highest frequency in any given band.

Mechanical dimensions are also given for all waveguides, along with their tolerances. This is especially valuable, since these figures can be used as a guide to minimum tolerances throughout the rest of a system under design. Engineers who do not work with microwaves on a regular basis will also be able to use this chart to find radius dimensions, type of flange available — either cover or choke — in both aluminum and brass; as well as dimensional information to help them determine frequency ranges consistent with the mechanical and dimensional requirements of the equipment with which they are working.

Finally, the Narda designation number for each waveguide is also indicated, along with the EIA and military numbers, to facilitate ordering.

Copies may be obtained on request.

Circle Reader Service Card 110

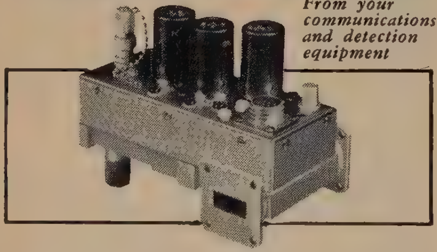
— mwj —

MIXER-PREAMPLIFIERS

(For Maser and Parametric RF Amplifiers)

COMMAND MAXIMUM PERFORMANCE

From your communications and detection equipment



The LEL MMX-3 Mixer-Preamplifier covers the upper X-band from 10.5 to 12.4kmc. It provides stabilized IF-RF power gain of more than 25db over a 20mc bandpass centered at 60mc, with minimum noise figure making the MMX-3 ideally suited for Maser and Parametric post-amplification use as well as general microwave receiver applications.

Featuring:

Noise Figure ....9.0db nominal (Max. 9.5db)
Low Power Requirements ....170v @ 55ma

Send for comprehensive Microwave, IF, RF Amplifier Catalog.

LEL INC 380 OAK STREET, COPIAGUE, N. Y.

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IF YOU DEPEND ON FERRITES ...YOU DEPEND ON IRVAN

from microwave to recording
head frequencies, Irvan has a national reputation
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for ultrasonic, surface, centerless, OD and ID
grinding and has on hand over 30 grades of ferrite
material for "yesterday" delivery on your ferrite orders.

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BOSTON SECTION, IRE SPONSORS SPRING LECTURE SERIES

The Lexington High School Auditorium, Muzzy Street, Lexington, Mass. will be the scene of the Spring Microwave Lecture Series sponsored by the Boston section of the IRE.

There will be a series of six two-hour lectures, survey in nature, including "state of the art" information on current topics in microwaves.

Chairman of the Spring Lecture Series is Theodore S. Saad, President of Sage Laboratories, Natick, Mass.

The program for the series is:

LECTURE I MICROWAVE SYSTEMS

W. L. Pritchard

Raytheon, Wayland, Mass.

7:30 - 9:30 p.m. March 29, 1960

This lecture will cover such microwave systems as radar, communications, computers, and heating. A block diagram analysis will be given of each system. Special emphasis will be devoted to the discussion of problems for microwave component people. Included will be such items as choice of line types, tubes, antennas, sensitivity, and other basic considerations. Some attention will be given to the problems of microwave power transmission.

LECTURE II MICROWAVE TUBES

Dr. R. Hutter

Sylvania, Mountain View, Calif.

7:30 - 9:30 p.m. April 5, 1960

The first half of this paper will be devoted to a general discussion of the principles of microwave tubes. The second half will describe how these principles apply to existing tube types including Klystrons, Magnetrons, Backward Wave Oscillators, and Travelling Wave Tubes.

LECTURE III

PASSIVE COMPONENTS IN WAVEGUIDE

Dr. H. Riblet and E. Salzberg

Microwave Development Laboratories

Wellesley, Mass.

7:30 - 9:30 p.m. April 12, 1960

This lecture will be devoted to a discussion of waveguide components. Consideration will be given to the performance and limitations of such items as filters, cavities, couplers, rotary joints, duplexers, and mixers.

LECTURE IV

PASSIVE COMPONENTS IN COAX AND STRIPLINE

Dr. A. Oliner

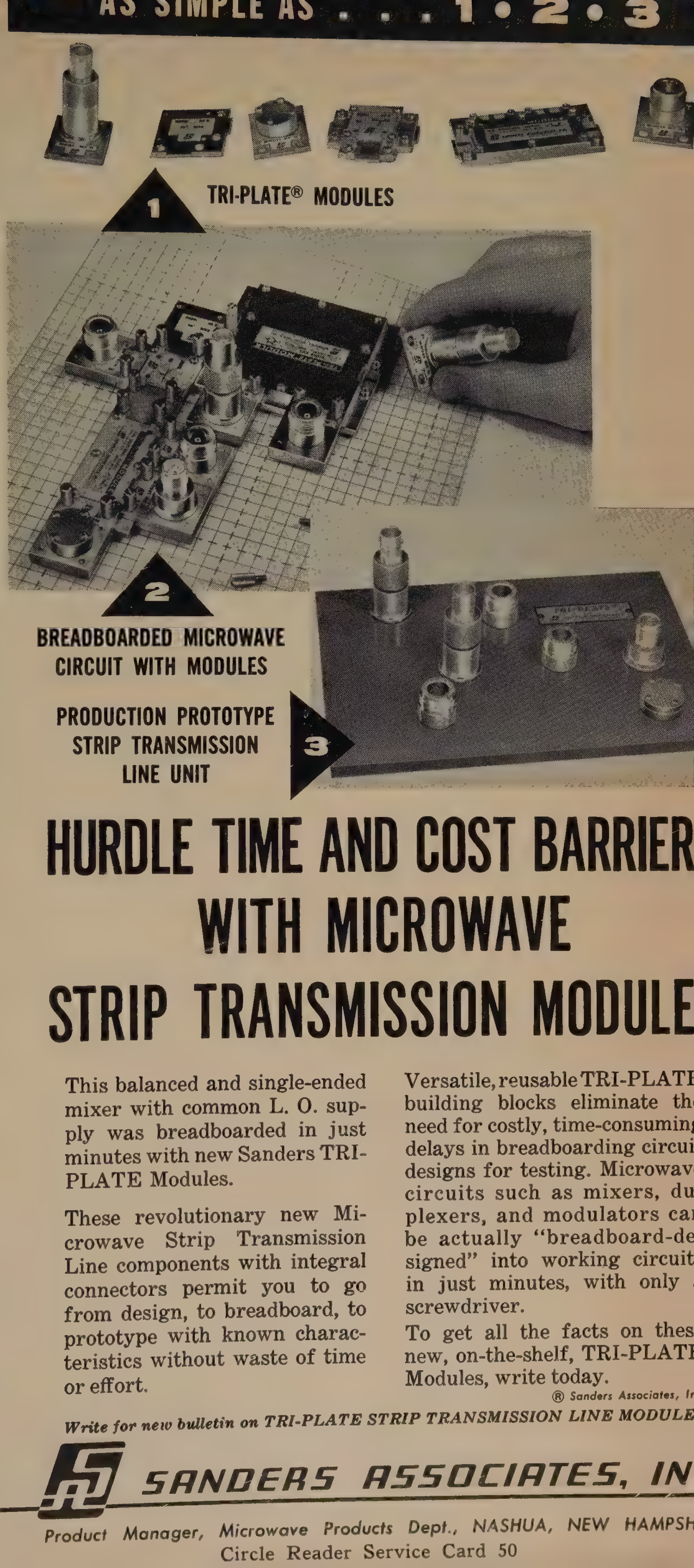
Polytechnic Institute of Brooklyn

Brooklyn, New York

7:30 - 9:30 p.m. April 20, 1960

This lecture will be generally similar to Lecture 5, but here the discussion will concern itself with components in coaxial line, stripline, and other special types of transmission line.

(*Continued on page 129*)



AS SIMPLE AS . . . 1 • 2 • 3

1 TRI-PLATE® MODULES

2 BREADBOARDED MICROWAVE CIRCUIT WITH MODULES

3 PRODUCTION PROTOTYPE STRIP TRANSMISSION LINE UNIT

HURDLE TIME AND COST BARRIER
WITH MICROWAVE
STRIP TRANSMISSION MODULE

This balanced and single-ended mixer with common L. O. supply was breadboarded in just minutes with new Sanders TRI-PLATE Modules.

These revolutionary new Microwave Strip Transmission Line components with integral connectors permit you to go from design, to breadboard, to prototype with known characteristics without waste of time or effort.

Versatile, reusable TRI-PLATE building blocks eliminate the need for costly, time-consuming delays in breadboarding circuit designs for testing. Microwave circuits such as mixers, duplexers, and modulators can be actually "breadboard-designed" into working circuit in just minutes, with only screwdriver.

To get all the facts on these new, on-the-shelf, TRI-PLATE Modules, write today.

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Write for new bulletin on TRI-PLATE STRIP TRANSMISSION LINE MODULE

SANDERS ASSOCIATES, IN

Product Manager, Microwave Products Dept., NASHUA, NEW HAMPSH

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New Products

SYLVANIA ADDS KU BAND MIXER TO "MICRO-MIN" MICROWAVE DIODE LINE

Latest addition to a line of miniaturized microwave diodes designed and produced by Sylvania Electric Products Inc. for specialized applications in radar, communications, missiles, satellites and other critical electronic equipment is a point contact microwave mixer for use in the Ku band frequency spectrum.

Designated Type IN918, the new microwave mixer is part of Sylvania's line of "Micro-Min" diodes which represent a major step in the miniaturization of radar and microwave equipment, according to Roger A. Swanson, product sales manager — microwave diodes of Sylvania's Semiconductor Division. In addition to meeting the electrical performance requirements of conventional ceramic or metal microwave diodes up to ten times their size, "Micro-Min" diodes "are also their match in ruggedness and stability," he added.

Mr. Swanson said the maximum conversion loss of the new silicon diode is less than 7.5 db while the output noise ratio does not exceed 2.5 times. Type IN918 operates as a mixer at 16,000 mc.

Sylvania's "Micro-Min" diodes are especially suited for the growing trend toward printed circuitry in microwave equipment. Hermetically sealed in miniature glass envelopes, they form an integral part of microwave circuits in wave guide, coaxial line, microwave strip transmission line, or any other transmission line. They also employ greatly simplified holders compared with those required by their larger counterparts.

Circle Reader Service Card 111

— *mwj* —

NEW MACRAWAVE LINE

Douglas Microwave Co., Inc., manufacturer of a large variety of standard microwave test equipment and components, announces the addition of a new and complete line of MACRAwave (large waveguide) test equipment and components. MACRAwave units include adapters, test horns, attenuators, signal samplers, switches, tuners, wave meters, etc., supplied in the following EIA designated tubing sizes: WR77, WR975, WR1150, WR1500, WR1800, WR2100 and WR2300.

Comprehensive descriptive literature on MACRAwave units may be obtained without cost or obligation.

Circle Reader Service Card 112

— *mwj* —

DC-BLOCKS FROM CASWELL

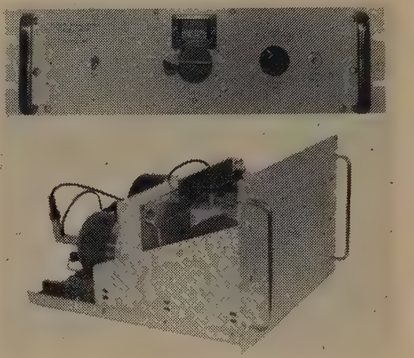
Two DC-Blocks which block the flow of direct current on a coaxial transmission line and yet transmit microwave energy have been announced by Caswell Electronics Corporation, San Jose, California.

These DC-Blocks provide 2000 volts of DC isolation between the two ends. The DC isolation is provided on both the inner and the outer conductor. Model N-050-A is designed for operation from 2 to 4 kmc, has a maximum insertion loss of 0.3 db, and a maximum VSWR of 1.3. Model N-050-B operates from 1 to 3 kmc, has a maximum insertion loss of 0.2 db, and a maximum VSWR of 1.25. Both of these units are 3 15/16″ long and are provided with type "N" female connections.

Circle Reader Service Card 113

— *mwj* —

REMOTE TUNED SIGNAL SOURCE ANNOUNCED



The Model SS 305 Remote Tuned Signal Source is now available from Scientific-Atlanta, Inc., Georgia manufacturer of microwave and antenna instrumentation.

The new instrument is primarily designed to provide a source of remotely tunable r-f power for antenna pattern ranges. Suited to remote tuning, control, and band switching at distances of more than a mile, the Model SS 305 covers the frequency range from 50 to 2000 mc. calibrated to an accuracy of ± 2.0%. The instrument provides a minimum r-f power output of 80 milliwatts across an impedance of 50 ohms. This output can be sine or square wave modulated.

A convenient servo null lamp indicates completion of tuning. The new Remote Tuned Signal Source can be retuned to a given frequency with an accuracy of ± 0.5%.

All three sub-units are mounted on standard 19″ wide rack mounting panels. The remote tuning unit and the power supply and servo units are mounted on 5-1/4″ high panels. The r-f oscillator unit is mounted on a 12-1/4 panel. Net weight is 105 pounds.

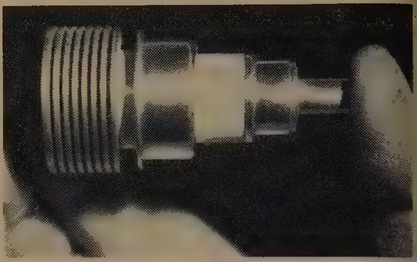
Price of the Model SS 305 Remote Signal Source is $3,850 f.o.b. Atlanta, Georgia.

Circle Reader Service Card 114

— *mwj* —

G.E. IMPROVES GL-6897

An improved, ruggedized version of the GL-6897 high mu, coplanar ceramic lighthouse triode has been announced by General Electric's Power Tube Department.



The new GL-6897, designed for reliable long life CW operation, has a typical power output of 20 watts at 1850 mcs with 33 percent plate efficiency, plate current of 100 ma, plate voltage of 600 v, and RF drive power of 2.5 watts.

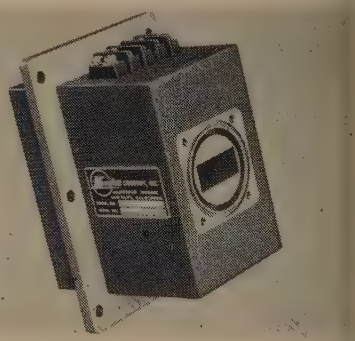
It is shock tested to 400 g's, and can be purchased to specification MIL-E-1/1037A.

The GL-6897 is immediately available in production quantities for microwave frequency communications service applications in grounded-grid, power amplifier, oscillator or frequency multiplier circuits. In such service, it will operate at frequencies up to 2900 mcs.

Circle Reader Service Card 115

— *mwj* —

NEW HI-POWER SWITCH ATTENUATOR ANNOUNCED BY KEARFOTT MICROWAVE DIVISION



A new Ferrite Switch Attenuator that may be used in high power transmitter circuitry is now being marketed by Kearfott Company Inc., Microwave Division, Van Nuys, California.

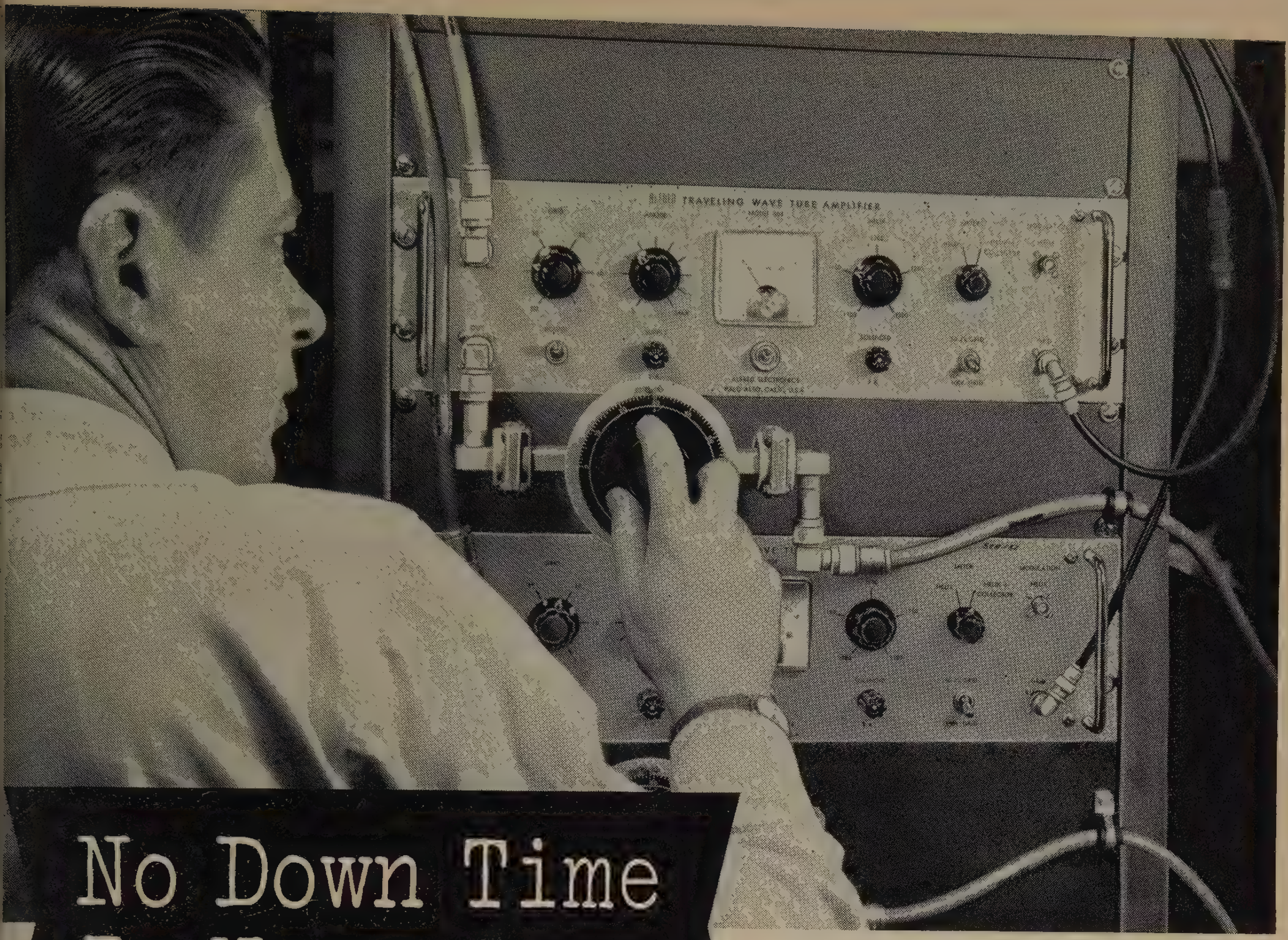
Designated as Model No. W662-3A-2, the new unit is ideal for range adjustment, static testing and slow modulation up to 250 KW. It will also increase isolation between high power switched channels.

Specifications are as follows:

Frequency Range: 8.5 to 9.6 KMC; Maximum Attenuation: 35 DB Min.; Minimum Attenuation: .5 DB Max.; VSWR Max.: 1.3 Bi-Lateral; Peak Power: to 250 KW; Average Power at 250 W; Switching Time: 20 Milliseconds; Switching Rate at 2 CPS; Driving Power: 100 W Max.; Weight: Less than 4 pounds; Size: 3-½″ long x 3-¾″ wide x 5-¼″ high.

Further information on the new Model W662-3A-2 Hi-Power Switch Attenuator is available on request.

Circle Reader Service Card 116



No Down Time Is Normal . . .

Alfred Electronics Model 504 Microwave Amplifiers, in use at Hughes Aircraft Co., Culver City, California

with ALFRED Microwave Amplifiers

ese Alfred TWT microwave amplifiers have seen con- uous service at Hughes for over 9 months. There has een practically no down time even for replacement of TWT tubes. Used in the RF portion of a missile testing stem, the Alfred units provide high gain, wide band, t response and low spurious modulation from 8 to 12.4 kmc. Hughes engineers praise the functional layout of the Model 504, its simple operation and reliable performance.

In short, Hughes finds the Alfred 504 Microwave Amplifiers good, sound, straightforward reliable instruments. We think you will too.

KEY SPECIFICATIONS—ALFRED MICROWAVE AMPLIFIERS

	Model	Frequency Range kmc	Gain db (min)	Power Output (min)	Price
General Purpose Amplifiers for AM, Pulse and Phase Modulation	505	1 to 2	30 db	10 mw	$1,550
	501	2 to 4			$1,390
	503	4 to 8			$1,490
	504	8 to 12.4			$1,490
	549	10.5 to 16			$3,550
Medium Power Amplifiers	5-6752	1 to 2	30 db	1 w	$2,290
	512	2 to 4	30 db 20 db	1 w Pulsed 100 mw CW	$1,850
	502	2 to 4	30 db	1 w	$1,390
	5-6868	2 to 4	30 db	10 w	$2,850
	506	4 to 8 4.5 to 7.5	27 db	.5 w 1 w	$2,290
	5-542	4 to 8	25 db	1 w	$3,190
	510	8 to 12.4	20 db	100 mw	$2,150
	509	8.2 to 11	27 db	.5 w	$3,150
	5-6996	8 to 9.6	30 db	10 w	$3,590
High Power Amplifiers	5-6826	2 to 4	30 db	1 kw pk	$4,850
Low and Medium Noise Figure Amplifiers	Amplifiers with low and medium noise figures are available either as packaged units or unitized for remote operation of TW tube and solenoid. Standard units provide coverage from .5 to 12.4 kmc with noise figures from 7 db up.				

MANY MODELS TO CHOOSE FROM

The 504 is just one model from the industry's most complete line of microwave amplifiers. For technical details and a demonstration arranged at your convenience, contact your nearby Alfred representative or write direct. Please address . . . Dept. 68-3.

ALFRED ELECTRONICS

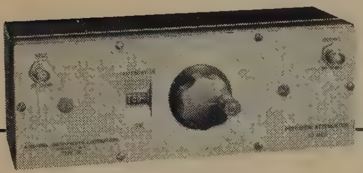
897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA 5

See us at the IRE show, Booth 1632

Circle Reader Service Card 51

Precision
I-F Attenuation

*Continuously Variable
over 80 db Range*



THE AIL TYPE 30

The AIL Type 30 Precision I-F Attenuator is a piston type attenuator operating in the waveguide below cutoff mode. It provides an attenuation range of 0 to 80 db above the minimum insertion loss to an accuracy of .005 db per db of increment.

Standard models are available at 30 mc and 60 mc center frequencies with nominal 50 ohms input and output impedances. Other frequencies and impedances are available on request.

The Type 30 is available in either cased, rack mounting or unmounted models.

Typical Applications

- *Noise figure measurements*
- *Calibration of directional couplers*
- *Calibration of R-F Attenuators*

Write for descriptive literature.

AIRBORNE
INSTRUMENTS
LABORATORY
DEER PARK, LONG ISLAND, NEW YORK
A DIVISION
OF CUTLER-HAMMER, INC.

PRECISION PHASE DETECTOR

AD-YU Electronics Lab., Inc., Passaic, N. J. has developed a new precision phase measuring instrument for the range 15 mc to 400 mc to meet the need of measuring phase shift of radar IF amplifiers, transmission networks and radar tracking systems. Type 205B1 utilizes a comparison method to achieve an accuracy of ±0.05° or ±1%. The sensitivity has been greatly increased with the use of balanced tuned amplifiers. In addition, balanced tuned amplifiers can also minimize the error due to harmonic contents and noise. Since constant time delay for all frequency components is important for faithful reproduction of radar signals, video pictures and other waveforms, this instrument is very convenient for measuring performance characteristics of transmission networks and amplifiers.

The specifications of this instrument can be summarized as follows: The accuracy is ±0.05° or ±1% of the dial reading. The resolution time is less than 0.1 micromicrosecond; the smallest phase angle which can be read on the dial is less than 10^{-13} x 360 x frequency in cps. The time delay of the continuously variable delay line can be adjusted from 0 to 2.8 milli-microseconds. Two step variable delay lines, have a total delay of 37.5 millimicroseconds in E_1 channel and 7.5 millimicroseconds in E_2 channel (in steps of 1 millimicrosecond). The minimum input signal depends on the sensitivity of the receiver; approximately 20 microvolts for a receiver having 5-microvolt sensitivity, and approximately 2 volts minimum is recommended for using the panel meter as indicator. The characteristic impedance is 50 ohms nominal for both input and output; type N connectors are used throughout.

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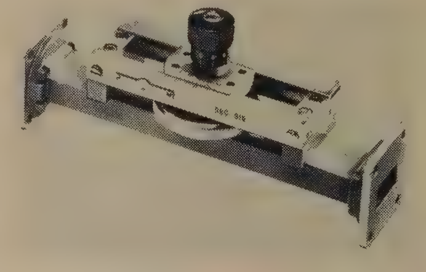
— *mwj* —

VARIABLE STUB TUNERS OFFER EXCEPTIONAL PRECISION



A complete line of precision variable stub tuners covering the frequency range from 2.6 KMC to 90 KMC is announced by DeMornay-Bonardi, Pasadena, Calif. The tuners are designed to create impedance matches in both microwave and ultramicrowave systems with exceptional accuracy.

Units in the range of 2.6 to 18 KMC ar
equipped with calibrated position contro
for both insertion and probe travel. A ne
scale and vernier provides precise resetta
bility on longitudinal travel, and a new mi
crometer scale on the probe supplies instan
accurate measurement of penetration. Th
probe is non-rotating, hence probe wobbl
is eliminated. The probe support has
dissipative insert which eliminates radiatio
effects. VSWR as high as 20:1 can b
tuned out with an accuracy of 1.02.

Units in the 18 to 90 KMC range a
engineered specifically for accuracy in thes
higher frequencies. All of the above fe
tures are available, plus micrometer pos
tioning which provides readability t
.0001". Threaded holes in these instru
ments provide for direct attachment t
waveguide supports.

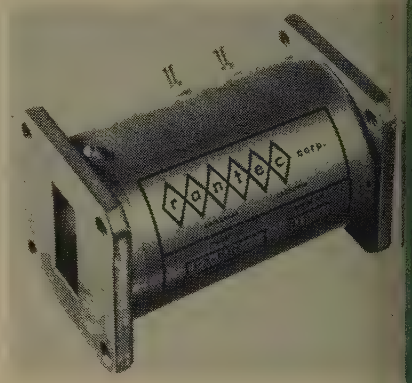
Flanges on all units meet MIL standar
for each waveguide size. All wavegui
RF surfaces are plated nickel over silv
over copper.

Literature DB-919 sent on request.

Circle Reader Service Card 118

— *mwj* —

TEMPERATURE COMPENSATED RECIPROCAL FERRITE PHASE SHIFTER



Rantec Corporation Model PX 1
X-Band temperature compensated fe
rite shifter produces ±90° of phase sh
maintaining absolute phase stability wit
±15° over the temperature range —10
to +100°C. Special matching techniq
are utilized which maintain the input VSW
at less than 1.15:1 for all control coil c
rent ranges over the temperature range s
cified. Control coil impedance is 200 oh
and requires 100 ma current for maxim
phase shift. The unit is rated at 2 K
peak, 2 watts average. Also available
other frequency bands, the new fer
phase shifter is manufactured by Ran
Corp., Calabasas, Calif.

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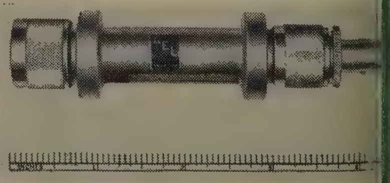
— *mwj* —

AEL DEVELOPS NEW GROUP C CRYSTAL VIDEO DETECTOR MOUNTS



(*Continued on page 102*)

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Remove and file

MICROWAVE

FERROTEC

FERRITE

COMPONENTS

FERROTEC INC. 217 CALIFORNIA STREET, NEWTON 58, MASS.

- DESIGN
- DEVELOPMENT
- PRODUCTION

FERROTEC'S comprehensive, standard line of microwave ferrite components answers the microwave system design engineer's need for ferrite components in the great majority of his applications. These standard components are fabricated from stock designs, and are readily available. The components are supplied in a choice of either aluminum or brass, limited only by design requirements. When ordering, please specify waveguide type and flanges.

Resonance Isolators

	Frequency MC	Range	Waveguide Size	Isolation Min. db	Insertion Loss Max. db	VSWR Max.	Power Peak	Aver.	Length* In.	Model No.
coaxial	2000	4000	⅜ N	10	1.0	1.20	—	10W	8.5	I-311L
	2200	2400	⅜ N	25	1.0	1.20	—	10W	8.5	I-312L
	4400	5000	⅜ N	20	0.8	1.20	—	10W	6.0	I-313L
	5000	6000	⅜ N	20	0.8	1.20	—	10W	5.25	I-314L
	2600	3600	⅞ LC	10	0.8	1.20	—	250W	12.0	I-315M
test equipment	2600	3950	RG-48/U	20	1.0	1.20	50KW	50W	14.0	I-151L
	3950	5850	RG-49/U	25	1.0	1.15	30KW	30W	10.5	I-152L
	5850	8200	RG-50/U	30	1.0	1.15	25KW	25W	8.5	I-153L
	7050	10000	RG-51/U	30	1.0	1.15	20KW	20W	8.0	I-154L
	8200	12400	RG-52/U	30	1.0	1.15	20KW	20W	7.0	I-155L
	12400	18000	RG-91/U	30	1.2	1.15	15KW	15W	6.0	I-156L
	18000	26000	RG-53/U	25	1.5	1.15	5KW	5W	5.0	I-157L
	26000	40000	RG-96/U	20	2.0	1.15	5KW	5W	4.0	I-158L
high power	2700	2900	RG-48/U	10	0.4	1.10	5MW	4KW	14.0	I-316H
	4400	5000	RG-49/U	12	0.5	1.10	2MW	2KW	10.0	I-317H
	5400	5900	RG-49/U	15	0.5	1.10	500KW	500W	5.0	I-318H
	5400	5800	RG-50/U	12	0.5	1.10	750KW	2KW	8.0	I-319H
	7500	8500	RG-51/U	15	0.5	1.10	300KW	300W	2.6	I-320H
	8500	9600	RG-51/U	15	0.5	1.10	300KW	300W	2.4	I-321H
	8500	9600	RG-52/U	15	0.5	1.10	250KW	250W	2.4	I-322H
	7800	10000	RG-52/U	10	0.6	1.20	200KW	200W	3.0	I-323H
	8200	10500	RG-52/U	10	0.6	1.15	200KW	200W	2.5	I-324H
	8600	11000	RG-52/U	10	0.6	1.15	200KW	200W	2.5	I-325H
	16000	17000	RG-91/U	15	0.5	1.15	100KW	100W	1.5	I-326H
	34000	35000	RG-96/U	18	0.8	1.10	50KW	25W	2.3	I-327H
miniature	5400	6400	RG-106/U	15	1.0	1.15	15KW	15W	1.7	I-303L
	6400	7400	RG-106/U	15	1.0	1.15	15KW	15W	1.5	I-304L
	5700	5900	RG-106/U	25	0.8	1.15	15KW	15W	1.7	I-305L
	6700	7000	RG-106/U	25	0.8	1.15	15KW	15W	1.5	I-306L
	9200	10000	RG-67/U	20	0.6	1.15	5KW	5W	1.2	I-307L
	9200	10000	RG-67/U	25	0.8	1.10	5KW	5W	1.5	I-308L
	8500	9600	RG-67/U	25	0.5	1.10	10KW	10W	2.0	I-309L
	16000	17000	RG-91/U	20	1.0	1.15	5KW	5W	1.5	I-310L
microwave relay	5400	5900	RG-50/U	40	1.0	1.15	25KW	25W	5.0	I-171L
	5900	6400	RG-50/U	40	1.0	1.15	25KW	25W	5.0	I-172L
	6400	7000	RG-50/U	40	1.0	1.15	25KW	25W	5.0	I-173L
	7000	7500	RG-50/U	40	1.0	1.15	25KW	25W	5.0	I-174L
other types	2900	3200	RG-48/U	25	1.0	1.20	50KW	50W	14.0	I-328L
	3300	3600	RG-48/U	25	1.0	1.20	50KW	50W	12.0	I-329L
	4400	5000	RG-49/U	40	1.0	1.15	25KW	25W	6.0	I-330L
	5200	5700	RG-49/U	40	1.0	1.15	20KW	20W	5.0	I-331L
	7500	8500	RG-51/U	30	1.0	1.15	20KW	20W	3.5	I-332L
	8500	9600	RG-52/U	30	0.6	1.15	20KW	20W	3.0	I-160L
	9600	10400	RG-52/U	30	0.8	1.15	20KW	20W	3.0	I-333L
	10400	11200	RG-52/U	30	0.8	1.15	20KW	20W	3.0	I-334L
	13000	15000	RG-91/U	25	0.8	1.15	5KW	5W	3.0	I-335L
	15000	16000	RG-91/U	20	0.8	1.15	5KW	5W	1.5	I-336L
	16000	17000	RG-91/U	20	0.8	1.15	5KW	5W	1.5	I-337L
	20000	22000	RG-53/U	20	0.7	1.15	2KW	5W	1.6	I-338L
	23000	25000	RG-53/U	20	0.6	1.15	2KW	5W	1.6	I-339L

* All parts supplied with cover flanges unless otherwise specified.

Circulators

	Frequency Range MC		Waveguide Size	Isolation Min. db	Insertion Loss Max. db	VSWR Max.	Power Peak	Power Aver.	Length* In.	Model No.	
faraday rotators	2700	2900	RG-48/U	20	0.4	1.20	10KW	10W	22.0	R114L	3 Port
	3000	3300	RG-48/U	20	0.4	1.20	10KW	10W	21.0	R138L	3 Port
	5400	5900	RG-50/U	▌20	0.5	1.20	10KW	10W	17.0	R151L	4 Port
	5600	5900	RG-50/U	20	0.4	1.15	10KW	10W	9.0	R120L	3 Port
	7100	8500	RG-51/U	▌20	0.4	1.20	10KW	10W	13.5	R130L	3 Port
	7100	8500	RG-51/U	▌20	0.4	1.20	10KW	10W	15.25	R131L	4 Port
	8200	10000	RG-52/U	▌17	0.8	1.30	10KW	10W	12.5	R133L	4 Port
	8500	9600	RG-52/U	▌20	0.5	1.20	10KW	10W	7.6	R132L	3 Port
	8500	9600	RG-52/U	▌20	0.5	1.20	10KW	10W	9.0	R161L	4 Port
	8700	9000	RG-52/U	20	0.4	1.20	30KW	30W	6.0	R160L	3 Port
	9200	9500	RG-52/U	20	0.4	1.20	30KW	30W	5.0	R159L	3 Port
	10000	10250	RG-52/U	25	0.4	1.20	10KW	10W	4.0	R158L	3 Port
	10250	10500	RG-52/U	25	0.4	1.20	10KW	10W	4.0	R149L	3 Port
	13000	15500	RG-91/U	▌20	0.5	1.40	10KW	10W	9.0	R153L	4 Port
	15900	16100	RG-91/U	25	0.3	1.10	10KW	10W	3.0	R100L	3 Port
	16300	16500	RG-91/U	25	0.3	1.10	10KW	10W	3.0	R129L	3 Port
	35000	36000	RG-96/U	20	0.8	1.20	5KW	5W	4.0	R154L	3 Port
differential phase shift	2700	2900	RG-48/U	25	0.3	1.15	10KW	100W	26.0	D114L	
	2900	3200	RG-48/U	25	0.3	1.15	10KW	100W	26.0	D104L	
	5400	5900	RG-50/U	20	0.4	1.15	300KW	300W	17.0	D113M	
	7500	8500	RG-51/U	30	0.3	1.15	50KW	100W	11.0	D112L	
	7500	8500	RG-51/U	25	0.5	1.15	2KW	2KW	14.3	D116H	
	8500	9600	RG-51/U	30	0.3	1.15	50KW	100W	11.0	D111L	
	8700	9600	RG-67/U	25	0.5	1.15	150KW	200W	7.0	D100M	
	8700	9600	RG-67/U	25	0.5	1.15	250KW	300W	7.3	D200H	
	9200	10000	RG-52/U	25	0.5	1.20	50KW	650W	6.5	D115M	
	16000	17000	RG-91/U	25	0.4	1.15	100KW	50W	6.7	D118H	
	34100	35900	RG-96/U	20	0.5	1.20	40KW	40W	7.0	D101H	

note: ▌— broadband

* All parts supplied with cover flanges unless otherwise specified.

Switches

	Frequency	Square Wave Modulation Rate	Switching Time (to 90% Switched)	Isolation	Loss	Model No.
high power	8900-9200	—	10 millisec	25	.5	D201H
low power	3000-3300	100 cps	100 μsec	20	.4	R138LS
	5600-5900	1000 cps	50 μsec	25	.5	R120LS
	10250-10500	1000 cps	15 μsec	25	.5	R149LS
	15900-16100	1000 cps	20 μsec	25	.5	R100LS

TEE Circulators — Three Port

These miniature circulators are available at C and X Band frequencies. Isolation values of 20 DB and insertion loss of 0.3 DB can be maintained over a 2½ — 3% bandwidth.

Phase Shifters

For electronic phase scanning, phase shifters of the "Spencer-Reggia" type provide large values of phase shift for minimum driving power. Designs exist at C, X, and Ku bands. A typical unit at X band provides 360° variable phase shift in 3.5 inches over an 8% frequency range.

Modulators

Any ferrite circulator can be used to provide modulation of the RF energy. They can be employed as switches, modulators and variable attenuators. Both high and low power modulators can be chosen from the above listing of circulators.

In addition to this standard line, Ferrotec supplies special configurations designed to meet existing space limitations, or to meet specialized electrical or mechanical requirements. Ferrotec maintains a special prototype department, where custom requirements are expedited. Because Ferrotec also has a completely equipped ceramic laboratory for the development of special ferrite materials, the company is able to work closely with the microwave system design engineer in special ferrites to meet his new component needs. Ferrotec will be pleased to submit quotations on any of your microwave ferrite component requirements.

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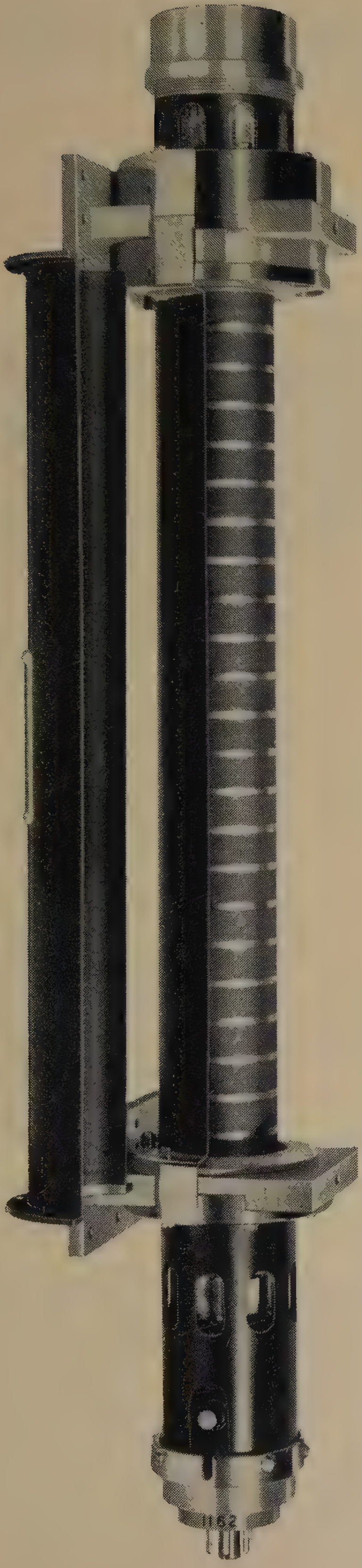
FERROTEC INC. 217 CALIFORNIA STREET, NEWTON 58, MASS.

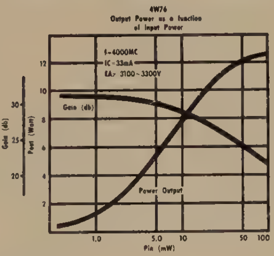
package-type TWT power amplifiers with NEC's new long life cathode

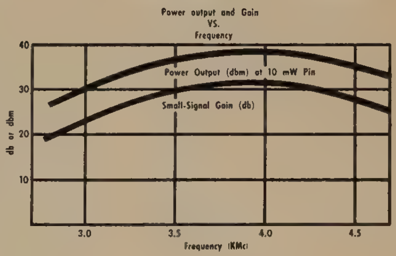


Production of traveling wave tubes at NEC began seven years ago and introduction of the package-type three years later. As chief supplier to Japan's complex network of microwave communications, NEC has become the world's largest maker of TW tubes. With the high development costs amortized and large manufacturing capacity, NEC is now able to supply these tubes at well below usual prices.

NEC's new doped nickel cathode core material, a 10-year development, increases both emission and tube life. It has been thoroughly field-proven in disc-sealed planar triodes for 2000-mc equipment of a large U.S. systems manufacturer (name on request). With its cooler operating temperature, evaporation rate of oxide is less than any other known core materials. This extends tube life up to 50%.

Designers will appreciate the compactness these tubes will give to their systems and operators the reliability and economy. Tubes connect to standard IEC waveguide flanges and can be shipped from stock. For specifications sheets, please write to Tokyo.





4W76

The 4W76 operates in the 4000-mc band and has nominal saturated power output of 10 watts. High amplification over a wide range of power levels results in small-signal gain of approx. 30 db. The band width at half-power points is 1400 mc, but the tube can be used in the frequency range of 2800 to 5000 mc.

Typical Operating Characteristics at 4000 mc

First Anode Voltage	2,640 V	Saturated Power Output	12.5 watts
Helix Voltage	3,220 V	Small-Signal Gain	32 db
Helix Current	0.7 mA	Noise Figure	approx. 25 db
Collector Current	33 mA	VSWR	less than 2 to 1 (from 3500 to 4300 mc)
Focusing Electrode Voltage	−40 V		

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PERMANENT MAGNET FOCUSED AMPLIFIERS

4W75	4000-mc band	1.5 watts	8W75	7000-mc band	1.5 watts
4W76	" "	5-10 watts	8W76	" "	5-10 watts
6W50	6000-mc band	5-10 watts	11W17	11000-mc band	1.0 watt

ELECTROMAGNET FOCUSED AMPLIFIERS

4W85	4000-mc band	0.1 watt	4W72A	4000-mc band	1.5 watts
4W86	" "	1.0 watt	7W52	6000-mc band	5-10 watts

Advantages of package-type

NO focusing or impedance matching at installation
NO dummy space for removal
NO power source or current stabilizer for electromagnet

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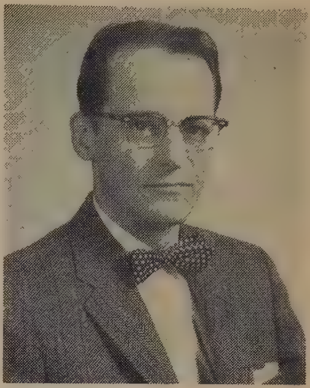
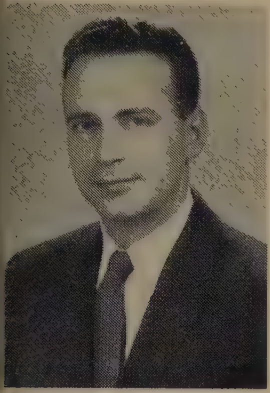


NNETH J. BUTTON received the B.S. degree in physics in 1950 and the M.S. ee in nuclear physics in 1952 from the University of Rochester. He worked at JR Cyclotron Laboratory in high-energy particle physics before accepting his ent position with the Massachusetts Institute of Technology. At Lincoln Labory, he became engaged briefly in radar system work, in the theory of micro- propagation in ferrite-loaded transmission lines and in the theory of romagnetic propagation in tensor media, both magnetic and semiconducting. ntly, Mr. Button has turned to the study of the energy band structure of conductors through the use of infrared spectroscopy.

Mr. Button is a member of the American Physical Society.



DAVID C. HOGG, received his B.Sc. from the University of Western Ontario in 1949, and his M.Sc. and Ph.D. from McGill University in 1950 and 1953.

Dr. Hogg joined Bell Telephone Laboratories in July, 1953, and has worked at the Holmdel Laboratory. He has been engaged in studies of artificial dielectrics for microwaves, antenna problems, and over-the-horizon and millimeter wave propagation as a member of the Radio Research Department.

During World War II, Dr. Hogg was in the Canadian Army and spent five years in Europe. From 1950 to 1951 he was engaged in research for the Defense Research Board of Canada. He is a member of *Sigma Xi* and Senior Member of IRE.

W. W. MUMFORD majored in mathematics and physics at Willamette University, graduating with an A.B. degree in 1930. He then joined the Technical Staff of the Bell Telephone Laboratories with the Radio Research Department at Holmdel, N.J. He has worked on ultra short wave propagation and microwave components for radio relay systems.

During the war he was engaged in developments for Radar. In 1953 he transferred to the Military Development Department at Whippany, N.J., where he is currently engaged in exploratory development. Mr. Mumford's contributions in the microwave field include the directional coupler, wide-band coaxial to waveguide transducers, helix to waveguide transitions as used in the traveling wave tube and the gas-discharge noise generator.

He was awarded the Fellow Grade of the IRE in 1952 and has served on the Administrative Committee of the IRE's PGMTT continuously since its formation. He has held the offices of secretary, vice chairman and chairman of that group. Currently he is chairman of the awards committee of the PGMTT and is also a member of PGED and PGFP.

HARD M. STEERE received the B.S. in Electrical Engineering degree from ama Polytechnic Institute in 1935. He was granted the M.S. degree after two of study and teaching at the Massachusetts Institute of Technology in 1948. He has worked for the Advanced Development Labs of RCA in Camden and Standards Laboratory of the Memphis Light, Gas, and Water Division.

Professor Steere began teaching in 1942 in the Electrical Engineering depart- t and the Signal Corps' Pre-Radar School at the Alabama Polytechnic Institute. 955, he was named to the Electrical Engineering faculty of the Louisiana Poly- nic Institute.

Professor Steere is a Senior Member of the IRE and director of the Shreveport, section. He is also a member of AIEE, ASCE, NSPE, *Tau Beta Pi, Eta Kappa* and *Sigma Xi.*

RECENT RAYTHEON DEVELOPMENTS
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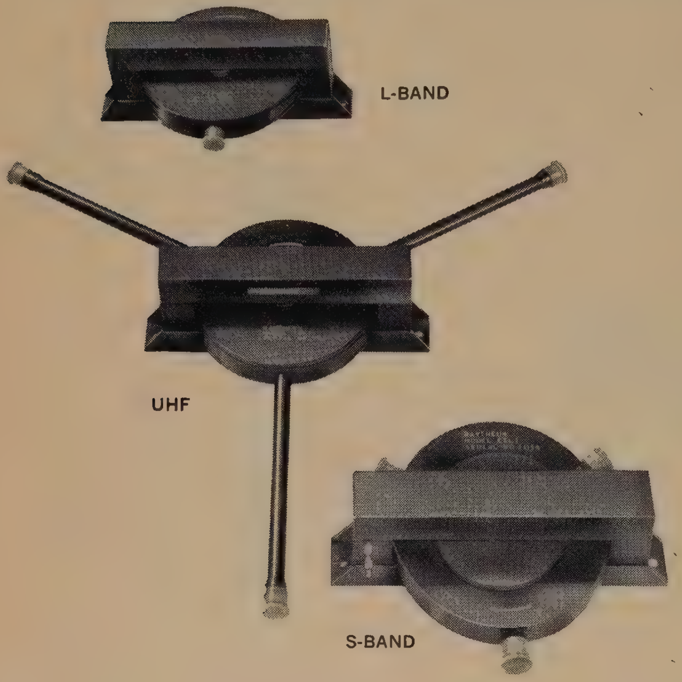
NEW 3-PORT CIRCULATORS FOR MASERS PARAMETRIC AMPLIFIERS & RADIO ASTRONOM



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The three-port circulators, designed for use with co ial line, are supplied with fixed permanent magn or with tunable electromagnets for operation ove broader band. Insertion loss is typically .4 db mi mum.† Isolation on all units is 20 db minimum. VS is 1.25 maximum. See typical specifications at

To learn more about these significant developm or for information about other important Rayth advances in microwave ferrite devices, please w stating your particular area of interest, to the add below.

†L&S bands only. UHF insertion loss is typically .5 db.

TYPICAL SPECIFICATIONS

		L & S bands	
	UHF	Tunable units	Fixed units
Frequency range	any freq. from 350-800	any freq. from 800-3000	any freq. from 800-3000
Bandwidth	±5 mc	±50 mc above 1000 mc ±40 mc under 1000 mc	±25 mc above 1000 mc ±20 mc under 1000 mc
Isolation	20 db min. 25 db max.	20 db min. 30 db max.	20 db min. 30 db max.
Insertion loss	.4 db min. .6 db max.	.3 db min. .4 db max.	.3 db min. .4 db max.
VSWR	1.08 min. 1.25 max.	1.08 min. 1.25 max.	1.08 min. 1.25 max.
Power (av.)	5 watts	5 watts	5 watts
Power (peak)	5 kw*	5 kw*	5 kw*
Wt. (max.)	10.0 lbs.	10.0 lbs.	9.0 lbs.
Max. diam.	7½ in. excluding arms	7½ in.	7½ in.

*With type N connector. Powers as high as 90 kw are possible with type HN connector.

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storical Sketch of FERRITES and their Microwave Applications

KENNETH J. BUTTON
LINCOLN LABORATORY
Massachusetts Institute of Technology • Lexington, Massachusetts

NTRODUCTION

he explosive developments and steady progress in the ication of ferrites and related materials to practical owave devices have had their foundations in the large of fundamental information that was accumulated een 1930 and 1955. As is true of most basic research, pursuit of this information was not directed toward, even motivated by, the central theme of application as equently is today. A review of some of these significant but isolated, findings will reveal their application to ent problems and some of the most recent developts (such as UHF and high-power devices) may be erstood in terms of the fundamental properties that demonstrate so clearly. This paper will deal briefly that part of the background material which seems e pertinent to the contemporary designers and users errite devices.

though the early ferrite studies were first applied to low-loss permeable cores for high-frequency transers, several useful general concepts emerged as measments were extended to higher frequencies:

.) The ferrite magnetic structure was worked out the Néel theory of ferrimagnetism was announced. se models are now used to adapt the material to dift microwave applications by replacing some of the atoms in the ferrite with other magnetic or nonmag atoms. More of these mixed, substitution and hybrid erials have been used recently to extend the versatility errite isolators, circulators and switches.

2) Two distinct magnetic loss mechanisms were debed quantitatively; a loss due to the motion of domain s driven by the r-f field and a loss due to ferromagnetic nance in the internal magnetic fields of the ferrite. n of these are again of immediate interest to those who gn or use ferrite components at low microwave fre cies or in the UHF.

3) A "tunable" ferromagnetic resonance induced by xternal dc magnetic field was discovered to occur at a uency $f_r = \gamma H_r$ which depends on the intensity of an *rnal* field. This was predicted by a classical theory, ied experimentally and detailed equations were worked expressing the resonance frequency in terms of the applied field, demagnetizing factors and saturation magnetization.

(4) A tensor permeability of the ferrite was derived which proved that microwave devices could be built which would be nonreciprocal. A cavity resonance method of measuring each component of the permeability tensor was devised so that the microwave properties of any ferrite could be described completely.

(5) The fundamental nonreciprocal devices were demonstrated at X-band; the Faraday rotator, the resonance isolator, the nonreciprocal phase shifter (circulator), and the field-displacement isolator.

(6) The deterioration of ferrite performance at high power levels was described in detail and was shown to depend on the half-width of the ferromagnetic resonance absorption line. The appropriate ferrite can now be selected for operation in high-power systems.

(7) A large effort was made, both theoretically and experimentally, to design isolators and circulators at frequencies at least an order of magnitude below and above the X-band region where all of the devices had been demonstrated originally. The isolator figure of merit, $F = (4f/\gamma \triangle H)^2$ was derived which showed that a low frequency device requires the use of a ferrite having a narrow resonance line, $\triangle H$, and, if possible, a small effective g-factor (γ). Practical devices now operate at frequencies as low as 400 mc and as high as 140 kmc.

The items listed above represent one view of the important highlights which have contributed to the current state of the art. This review cannot be comprehensive or complete and the material has been selected on the basis of its potential value to the microwave engineer.

II. DEVELOPMENT AND MEASUREMENT OF SYNTHETIC FERRITES

Large dc resistivity, more than a million times larger than the magnetic metals, indicated that the ferrites might be useful in reducing eddy current losses in transformers and inductors. The magnetic measurements by duBois (1890) and Pierre Weiss (1896) had shown that the Curie temperature and saturation magnetization of natural magnetite crystals were similar to nickel. The earliest synthetic ferrites made by Hilpert (1909) had not been suitable, however, because of low permeability, large losses and poor reproducibility. Therefore, the high-permeability metal-alloy ribbons for laminated core applications and the development of powdered-metal cores useful up to one megacycle delayed the development of ferrites until about 1930.

The need for low-pass permeable cores at frequencies above a few megacycles arose in the early 1930's and the research group at Philips' Laboratories in Eindhoven turned again to the synthetic ferrites for the solution of this problem. Snoek (1936-49) concentrated on the synthesis of polycrystalline materials and the measurement of their magnetic permeability and magnetic losses, initially at radio frequencies and eventually into the microwave range.

Magnetic Loss Processes in Ferrites

Since the eddy current losses are negligible and the hysteresis losses are small for small r-f driving fields, the early studies involved the description and identification of what appeared to be a frequency-dependent spin resonance loss. Figure 1(a) shows the peak in the loss (μ'') at about 200 mc in the nickel ferrite of the Ferroxcube IV series. We are concerned with this loss mechanism because it extends into the microwave region. If it were a spin resonance absorption, there would be two requirements: 1) a dc magnetic field about which the precession of the spin dipoles can take place (very much as a gyroscope precesses in a gravitational field); 2) an alternating magnetic field which drives the precession at (or near) the natural precession frequency of the spin dipoles. The natural precession frequency depends on the dc field intensity which can be supplied by (1) internal anisotropy fields, (2) internal demagnetizing fields from domain walls, cracks or imperfections, or (3) externally applied fields. If no external field is applied, as in Figure 1, the peak absorption would occur at a frequency $f_r = \gamma H_{inter}$
where γ is equal to 2.8 mc/oersted. The value of H_i, a
thus f_r, can be changed by changing the composition
the material.

The resonance loss peak of Figure 1 was accepted
spin resonance in the internal anisotropy field until Ra
Wright and Emerson (1950) resolved two narrow pea
shown in Figure 1(b) which had formerly coalesced
form the single broad peak of Figure 1(a). It was sho
that the high frequency peak near two kmc was caused
spin resonance in the internal fields and the r-f peak
sulted from reversible motion of the domain walls whi
are driven by the r-f field. Therefore, the microwave pe
of Figure 1(b), with which we are most concerned, c
occur at a frequency as high as

$$f_{max} = \gamma\,(H_{int})_{max} = \gamma\,(H_{anis} + 4\pi M_s) \quad (1$$

which can be as high as 10 kmc. The anisotropy field (
to 300 oersteds) is the field required to turn the m
netization out of the easy direction. The saturation m
netization (up to 3500 oersteds) appears because of m
netic poles induced on the faces of internal domain wa
when the domains are rotated slightly by the r-f field. T
latter mechanism was described by Polder and S
(1953). The experiments of Pippin and Hogan (195
in high-density ferrites have completely verified the id
tity of these losses.

If the external field applied to a ferrite device is su
ciently large to sweep out the domain walls, the loss p
at r-f is removed and $4\pi M_s$ drops out of Equation 1. T
moves the microwave peak to low frequencies. If the
plied field is small, however, the only escape is to red
$4\pi M_s$ until f_{max} is less than the operating frequency.
frequencies below 3000 mc, this requires specially-do
ferrites. To see how this is done, it is helpful to look i
the magnetic structure.

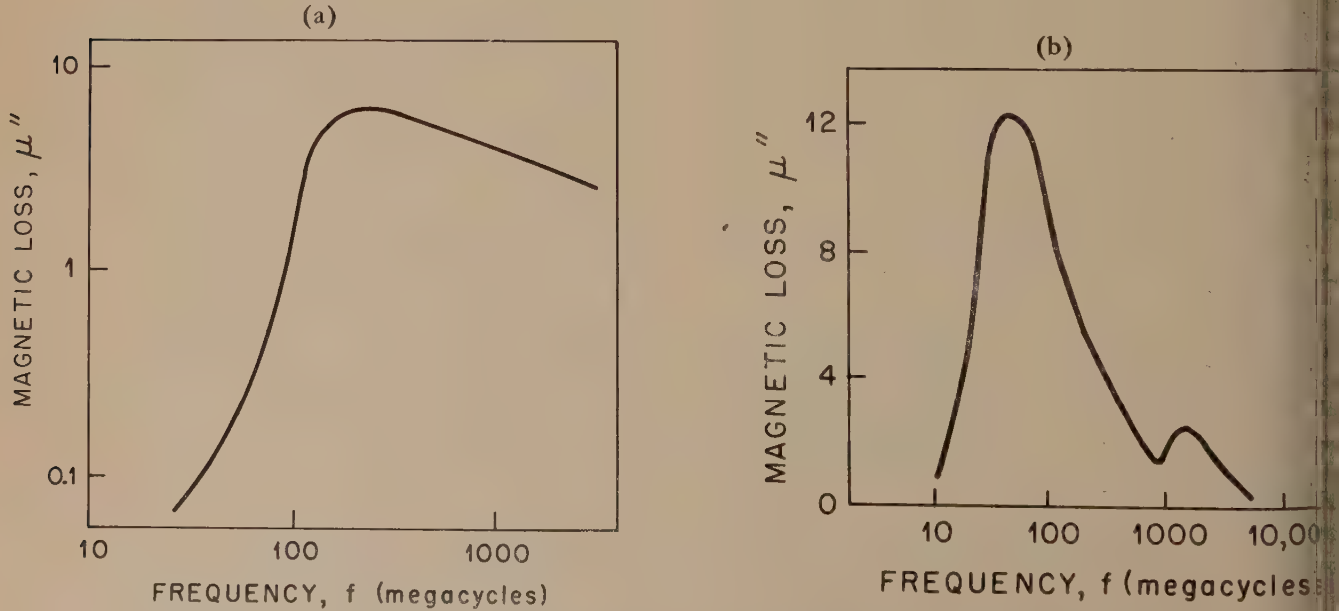


Figure 1 — The dissipative part of the ferrite permeability for unmagnetized (a) Nickel ferrite with low density;
(b) Ferramic A in which two resonances were observed by Rado, Wright and Emerson.

e Inverted Spinel and Ferrimagnetism

Magnetite, the naturally occurring ferrite, has the for-
la Fe_3O_4 but in this context must be written as
$+ O \cdot Fe_2{}^{3+} O_3$. The family of synthetic ferrites is
resented by $MO \cdot Fe_2O_3$ where the divalent iron atom
replaced by M, a divalent metal ion such as Ni, Co,
, Mg, Ca, Zn, Cd, Ba, Cu or a mixture of these. More
ently, some of the trivalent iron atoms are replaced by
h trivalent metals as aluminum to produce the so-called
bstitution ferrites" or the "ferrite-aluminates."

The ferrites crystallize in a structure called the "spinel"
ich is named after the mineral $MgAl_2O_4$. The unit cell
the ferrite has cubic symmetry and contains 32 oxygen
ons, 16 trivalent cations and 8 divalent cations. The
nition of the *normal* spinel requires that the eight
alent metal ions shall occupy "A sites" (tetrahedral
s where each metal ion is surrounded by *four* oxygen
s) and that the 16 trivalent ions shall occupy "B sites"
tahedral sites where each metal ion is surrounded by
oxygen ions). However, x-ray analyses of magnetic
ites by Barth and Posnjak (1932) revealed that diva-
ions interchange position with eight of the trivalent
s to form the *inverted* spinel, a structure that is required
the existence of ferromagnetic properties. To explain
se facts, Néel (1948) announced his celebrated theory
anti-ferromagnetism and ferrimagnetism in which he
tulated that spins of adjacent magnetic atoms are
ned *oppositely*. Furthermore, the closer the magnetic
ms, the stronger the tendency to align oppositely. There-
e, since the nearest neighbor of an atom on a B-site is an
m on an A-site, the A and B sublattices will be aligned
positely. Then, to satisfy this condition, the spins of
ms on the *same* sublattice must align parallel despite
r weak tendency to align alternately anti-parallel. This
the principle upon which different formulations are
ived.

he consequences of the theory are straightforward: An
erted spinel contains 8 trivalent iron atoms on each
lattice which almost cancel each other's magnetic effect
ing the 8 divalent magnetic ions to provide the net
gnetization of the material. Magnetization measure-
nts showed that dilution by the addition of non-mag-
ic atoms such as aluminum (B-sites) or zinc (A-sites)
kens the dominant anti-parallel forces between sub-
ices; sufficient dilution will permit the prevalence of
weak tendency of atoms on the same sublattice to align
rnately anti-parallel and the magnetization goes to zero.
ect verification of this Néel model* was eventually
ained from the results of neutron diffraction studies.

xed Ferrites and Substitution Ferrites

s this the key to the problem of operating ferrite de-
es at low microwave frequencies and the UHF? As a
sequence of Equation 1 it was stated that this source of
rtion loss could be removed by reducing the magneti-
ion until f_{max} was less than the operating frequency.
ution of the ferrite accomplishes this but the following
happens: (1) The Curie temperature decreases which
y make the device extremely temperature-dependent;
) For aluminum substitution, the saturation magnetization may go through zero and reverse; for nonmagnetic zinc substitution, the magnetization *increases* initially; (3) The width of the ferromagnetic resonance line changes abruptly; (4) The resonance may no longer appear at the expected frequency because the "constant" γ (2.8 mc/oersted) may change by a factor of three, either higher or lower.

These difficulties can be handled or turned to advantage by looking up some old data. Gorter (1950) and Guillaud (1949-51) had provided one of the earliest verifications of the Néel theory by adding $Zn^{2}+$ to an A-site forcing an $Fe^{3}+$ to a B-site where it crowds out, say, a $Ni^{2}+$. The magnetization rises as shown in Figure 2(a) despite the loss of a magnetic $Ni^{2}+$ because the ferrite now contains two effective $Fe^{3}+$ that formerly cancelled each other. However, the interaction energy between sublattices $E = kT_c$, has been reduced by nonmagnetic ion substitution resulting in a lower Curie temperature T_c and also an eventual reduction in magnetization as shown in Figure 2(a). The substitution ferrites containing non-magnetic *trivalent* atoms such as Al, Ga, Sc or Cr have been studied thoroughly by Guillaud and Michel (1951), Jones and Roberts (1952) and especially Maxwell and Pickart (1953-4). The latter demonstrated the compensation point shown in Figure 2(b) where the two sublattices have been adjusted to have equal and opposite magnetization. Further dilution reverses the magnetization and finally destroys it. Very low magnetization, aluminum-substituted ferrites are now widely used in UHF and low-microwave frequency resonance applications.

To understand how to make use of the sharply-changed effective γ and resonance line width in component design, the principle of induced ferromagnetic resonance must be developed.

III. FERROMAGNETIC RESONANCE

The basic phenomenon of ferromagnetic spin resonance was first predicted at microwave frequencies by Landau and Lifshitz (1935) on entirely theoretical grounds and the fundamental principle, $f_r = \gamma H_r$ was established. Kittel (1946) discussed the Landau-Lifshitz prediction and suggested the use of magnetic oxides to observe resonance using an external dc magnetic field. Griffiths (1946) recognized ferromagnetic resonance in his microwave experiments using a magnetic metal foil. Kittel (1947) interpreted Griffiths' observation and Yager and Bozorth (1947) made additional observations at K-band. Kittel completed his theory of ferromagnetic resonance by including the dependence of the resonance frequency on the shape of the specimen and Hewitt (1948) provided experimental verification using both a spherical and plane specimen of manganese-zinc ferrite. This Kittel Equation is still one of the most useful relations in ferrite device design:

$$f_r{}^2 = \gamma \{[H + (N_x - N_z) M] [H + (N_y - N_z) M]\}$$

(Kittel's Equation)

where the dc magnetic field is along the z-direction and $N_x + N_y + N_z = 4\pi$ are the demagnetizing factors of the specimen. This has been obtained from the classical equations of motion of the macroscopic magnetization vector and it has been shown by Polder (1948-9) and others that a more rigorous quantum mechanical treatment of the spin system gives the same result.

The Néel theory of ferrimagnetism and the experimental veri-
ion have been reviewed by Néel (1952) and Smart (1955).

Spectroscopic Splitting Factor

Several dozen important resonance experiments were performed between 1949 and 1955 in an effort to measure the g-factor precisely for various ferrites and hence, the constant $\gamma = ge/2mc$, in the Kittèl formula. The electron g-factor should be nearly 2.00 in the absence of spin-orbit coupling but larger values were obtained in microwave cavity experiments if the ferrite sample were larger than a few tenths of a millimeter or if it were mounted too near the cavity wall. After the techniques of the cavity measurements were perfected, Okamura, et al (1952) and Tsuya (1954) showed (from the frequency dependence of the g-factor) that an internal field due to the porosity of polycrystalline samples gave an *apparent* g-factor slightly larger than 2.00. Schlömann (1956) furnished a formula for this internal field due to porosity and anisotropy of polycrystalline ferrites.

Although g-factors as high as 2.3 had been reported, McGuire (1954) found effective g-factors as high as eight and as low as one in aluminum-substituted nickel ferrite near a compensation point as shown in Figure 3. Wangsness used the two-sublattice theory to explain this large variation.** The possibility of adjusting the resonance frequency by choosing γ in Kittel's equation from such a large range has recently been put to good use in device design.

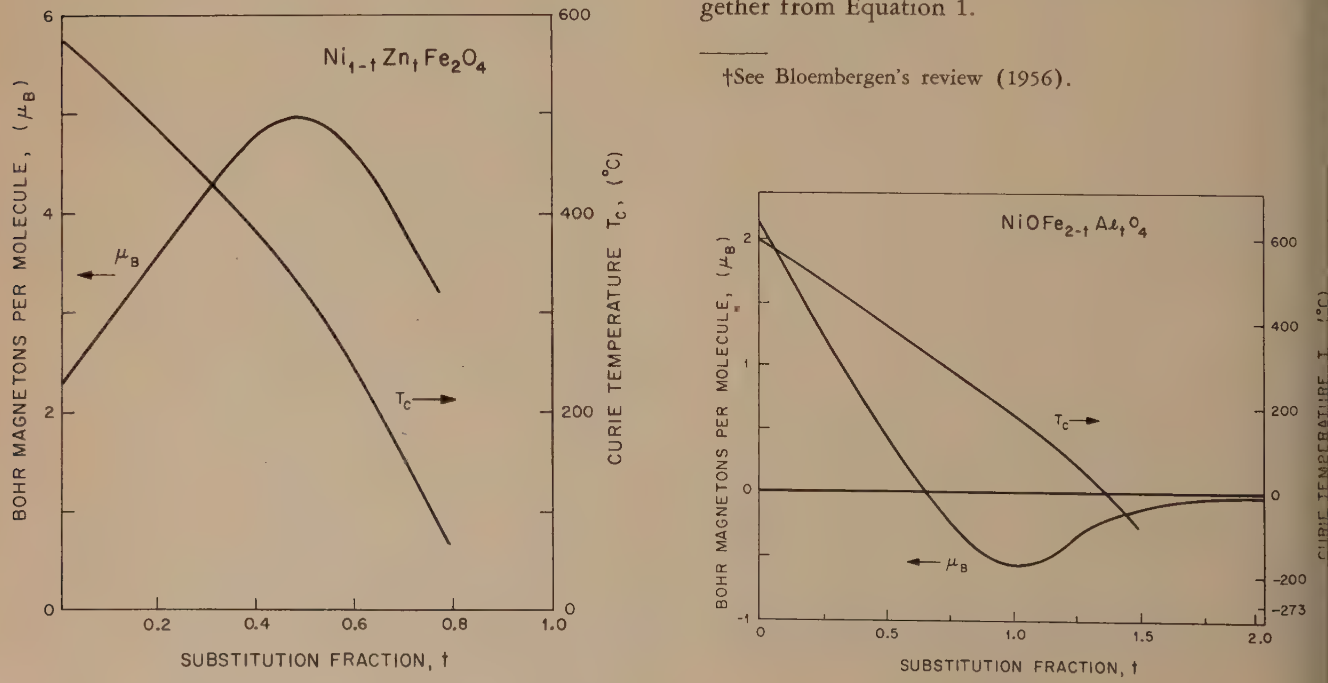
Ferromagnetic Resonance Line Width

The intrinsic line width is associated with the damping of the precession of the spin dipoles but the fundamental mechanism of damping has never been described quantitatively. Two phenomenological representations of the loss term have been developed and are suitable for practical purposes for describing the result of the damping of the macroscopic magnetization vector: the Landau-Lifshitz (1935) and the Bloch-Bloembergen† phenomenological damping terms. Both forms simply introduce resonance attenuation through the use of an arbitrary relaxation time or damping frequency which is usually obtained from a measured line width. This includes line-broadening often experienced because of internal fields set up by porosity, stresses and magnetic anisotropy. The resonance line width has recently become of the greatest practical importance with the advent of UHF and high-power applications.

Resonance in UHF Applications

The applied magnetic field required for resonance at a given frequency $f_r = \gamma H_r$ is usually so small at low frequencies, that all of the ferrite material may not be free of magnetic domains. Then the insertion loss due to Rado's resonance peak, (Figure 2(a) and Equation 1) must be reduced by lowering the magnetization. If this is done then the performance of low frequency devices depends largely on the remaining ferromagnetic resonance parameters: the factor γ and the resonance line width $\triangle H$. Lax (1955-6) derived the figure of merit $F = (4f_r/\gamma\triangle H)^2$ for a resonance isolator and $F = 2f_r/\gamma\triangle H$ for the nonreciprocal dispersive devices. The resonance frequency f_r is expressed in megacycles, the width of the resonance line $\triangle H$, is oersteds and $\gamma =$ 2.8 mc/oersted for a g-factor of two. Both of these formulas show that the smaller the product γ $(\triangle H)$ the lower may be the operating frequency without a sacrifice in the performance factor F.

The significance of the smaller g-factor (smaller γ) obtainable in ferrite aluminates as shown in Figure 3 is that a proportionately larger field is required for resonance at a given frequency. The larger field tends to sweep out the domains removing the term $4\pi M_s$ altogether from Equation 1.



(a)

(b)

Fgiure 2 — Magnetization (left scale) and Curie temperature (right scale) for nickel ferrite in which the substitution of (a) zi and (b) aluminum has been made. (After Gorter (zinc) and Maxwell and Pickart (aluminum)).

**Wangsness' review (1956) is recommended.

†See Bloembergen's review (1956).

onance under Conditions of High Signal-Power

he saturation of the spin system by high intensity al levels was discovered and studied by Bloem- gen, Damon and Wang (1952-4) when they noticed stantial line broadening and lowering and also an itional absorption peak under these conditions. This nomenon prevented the use of ferrites in high power ems for several years. Fortunately, a better under- ding was acquired through the theoretical work of lerson and Suhl (1955) and Suhl (1956). The latter ished a simple formula relating the line width to threshold signal intensity for the onset of the ad- nal subsidiary absorption:

$$h_{crit} = \triangle H\,(3\triangle H/4\pi M_s)^{\frac{1}{2}}.$$

hl then turned this high-power catastrophe to our ntage by inventing the ferromagnetic amplifier (57) which was demonstrated experimentally by Weiss (57). The work of Suhl and others also brought out important role which the excitation of spin waves at power plays in the nonlinear properties of ferrites.

MICROWAVE DEVICES

he nonreciprocal properties of ferrite-loaded devices end upon the tensor properties of the ferrite per- bility which were first pointed out by Polder 48-9) in his work on the theory of ferromagnetic nance. The tensor, rather than scalar, representation he permeability describes the manner in which the ium responds *differently* to different senses of cir- ly polarized incident radiation. The nature of this nomenon was well known to both experimentalists theorists who had worked on the Faraday and Kerr neto-optical effects. Therefore, to apply the existing vledge to ferrites, three immediate requirements arose wing Polder's announcement: (1) experimental veri- on of tensor properties of ferrites (Beljers, 1950), a practical demonstration of a microwave device aday rotator), and (3) development of the microwave y techniques for measuring the tensor permeability ifferent ferrite materials.

Faraday Rotator

circular wave guide containing longitudinally-mag- ed ferrite exhibits a net rotation of the TE_{11} mode be- the two contra-rotating circularly polarized compo- s of the mode behave differently within the ferrite. erts (1951) observed this and found his result to with Polder's theory of tensor permeability. Hogan 2-3) demonstrated his microwave gyrator and out- its use as a one-way transmission line, circulator, h, variable attenuator or modulator. A burst of ac- in the study of microwave Faraday rotators was ulated by Hogan's work and by the extensive meas- ents of Faraday rotation and loss by Sakiotis, Chait Kales (1953-5) and the theoretical work of Kales 3). Extensive theoretical treatments of electromag- propagation in ferrite-loaded circular waveguide have given by Gamo (1953), Suhl and Walker (1952-4) van Trier (1953).

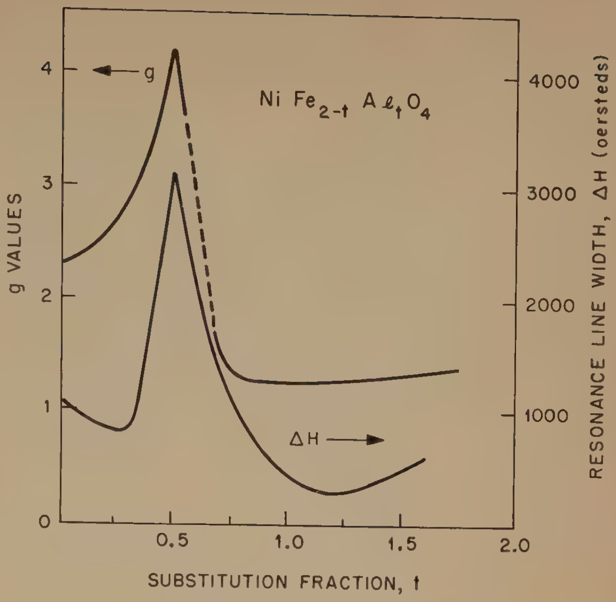


Figure 3 — The variation of g-value and resonance line width in aluminum-substituted nickel ferrite as a function of aluminum content. (After McGuire).

Tensor Measurements in Microwave Cavities

A small amount of ferrite in a resonant cavity will cause a shift in the cavity resonance frequency and a change in Q when an external magnetic field is adjusted for ferromagnetic resonance in the ferrite. The shift in frequency and change in Q can be related to the dispersive and dissipative components of the permeability by solving the ferrite-loaded cavity problem theoretically. The off-diagonal tensor components can also be measured if each of the two senses of circular polarization of a cylindrical cavity can be observed separately. Lax (1951) developed the technique for an ionized gas and Lax and Berk (1953) solved the theoretical problem for a cavity containing a small amount of ferrite. This technique, using degenerate TE_{111} cavities, was adopted and perfected by Artman and Tannenwald (1953-5) who studied the tensor susceptibilities of ferrite spheres as a function of applied magnetic field. Spencer, LeCraw and coworkers (1955-6) have made extensive studies of ferrimagnetic properties in this way. Cavity techniques are now used for the measurement of the fundamental resonance line width, temperature and frequency dependence of ferrite properties, the study of non-linear (high-power) effects, anisotropy, size and shape effects and multiple resonance peaks.

Rectangular, Helical, Stripline and Coaxial Devices

The understanding of the ferrite behavior obtained from the Faraday rotator and cavity measurements and also from the basic theoretical descriptions resulted in the demonstration of nonreciprocal phase shift and resonance attenuation in every kind of transmission geometry in which a suitable mode pattern could be found or created. It was only necessary to place the magnetized ferrite in the waveguide at a point where the r-f magnetic vector rotates as the wave pattern moves down the guide. Kales, Chait and Sakiotis (1953) recognized this immediately and described the rectangular waveguide nonreciprocal phase shifter and resonance isolator, both of which Sakiotis and Chait had demonstrated experimentally. Both theirs and Rowen's (1953) differential phase shifter used a transversely magnetized ferrite near one side of the guide. R. H. Fox (1954) designed the four-port circulator using these elements in conjunction with directional couplers or magic tees. Lax and Button (1954-8) solved a series of ferrite-loaded rectangular transmission line problems which described the modes and r-f field distortions. Fox, Miller and Weiss (1955) and Weisbaum, Seidel and Boyet (1956-7) introduced and perfected the field-displacement isolators. Weiss (1956) brought the widely-used rectangular isolator to a high degree of performance by introducing dielectric loading.

Resonance isolation in helical line was described by Cook, Kompfner and Suhl (1954) and Rich and Webber (1955). A balance stripline isolator was developed by Fix (1956). Antenna-scanning applications were described by Angelakos and Korman (1956) and Reggia, Spencer, Hatcher and Tompkins (1956). The ferrite and dielectric-loaded nonreciprocal coaxial devices for applications at UHF were described by Seidel (1957), demonstrated by Duncan, Swern, Tomiyasu and Hannwacker (1957) and analyzed by Button (1958).

Recent Reviews

Complete coverage of this active and productive field, particularly recent advances, could not be attempted here. However, readers who may be interested in pursuing this subject in more detail can find several competent reviews which furnish long lists of references to the specialized literature. These papers give a comprehensive discussion of new developments from different points of view. A great variety of components were covered by Fox, Miller and Weiss (1955). One of the most recent reviews was prepared by Lax (1958) which supplements his earlier review (1956). In both of these, particular attention is given to the recent advances in theoretical and experimental techniques for improving performance, bandwidth, and high-power behavior, as well as a description of new devices and new accomplishments at low and high frequencies. The October, 1956 issue of *The Proceedings of the Institute of Radio Engineers* contains a thorough summary of both the fundamental principles and the latest technical accomplishments. Bloembergen (1956) gave a complete treatment of basic resonance phenomena, Suhl (1956) worked out the detailed theory of high-power effects, Hogan (1956) reviewed the fundamental operating principles of the basic ferrite devices, Kales (1956) discussed the solutions of the propagation problem in guides containing ferrites and Heller (1956) treated the devices as circuit elements using scattering matrix theory.

Acknowledgment

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THE EFFECTIVE NOISE TEMPERATURE OF THE SKY

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Introduction

The proposed use of very low noise receivers such as mavars and masers in radar and communications systems has increased the importance of the noise that appears at the terminals of a receiving antenna since it may well set the limit on overall noise performance of the system. Antenna noise usually is specified by an effective temperature, the antenna temperature, which represents radiation from the sky, earth and environs into the antenna. This paper discusses the sky temperature due to noise from the galaxy, the sun and from the earth's atmosphere.

The output noise of an amplifier having gain G, noise figure F, and bandwidth B, is:

$$N = GFk290B \qquad (1)$$

when the generator noise temperature is 290° K. In many practical cases, for example, when the amplifier has an antenna connected to it as the generator, the noise temperature of the generator differs from 290°. In such cases, the output noise is:

$$N = Gk290B\,(F - 1 + \frac{T_g}{290}) \qquad (2)$$

where T_g is the generator temperature or antenna temperature (see Figure 1).

It is convenient to write Equation (2) in the form

$$N = GkB\,(T_g + T_e) \qquad (3)$$

where T_e is the equivalent (or effective) input noise temperature of the amplifier referred to the generator terminals or the antenna output terminals, in which case

$$N = GkB\,(T_a + T_e) \qquad (4)$$

Now the antenna temperature, T_a, depends upon what the antenna "sees," i.e., it depends upon the temperatures of the absorbing media which would absorb the transmitted power if the antenna were a transmitting antenna. If a fraction, α_1, of the transmitted power is absorbed by the sky and another fraction, α_2, absorbed by the ground and so on, the antenna temperature would be the summation of all the products of the fractions α_n and the noise temperatures of the different absorbers, thus:

$$T_a = \alpha_1 T_{sky} + \alpha_2 T_{ground} + \Sigma \alpha_n T_n \qquad (5)$$

The fractions α_1, α_2, and α_n will depend upon the antenna characteristics, such as beamwidth, spillover and sidelobes which may see the sun or other hot spots in the sky.

The equivalent input noise temperature, T_e, of the ceiver must include the effect of loss between the anten terminals and the amplifier, since some of the noise w originate in this lossy section. This may be taken in account by means of the relation:

$$T_e = (L - 1)\,T_L + L\,(F_r - 1)\,(290) \qquad ($$

where L is the power loss of the lossy section

T_L is the temperature of the lossy section
F_r is the noise figure of the amplifier which follows lossy section.

F_r, of course, may be expressed in terms of the equi lent input temperature of the amplifier thus:

$$F_r = 1 + \frac{T_{er}}{290}$$

Thus Equation (4) becomes

$$N = \frac{G}{L} kB\,[\alpha_1 T_{sky} + \alpha_2 T_{ground} + \Sigma \alpha_n T_n + (L - 1)\,T_L + L\,T_{er}]$$

where $\frac{G}{L}$ is the gain from the antenna terminals to output.

Noise from the Sun

First let us discuss briefly the radio frequency noise f the sun.

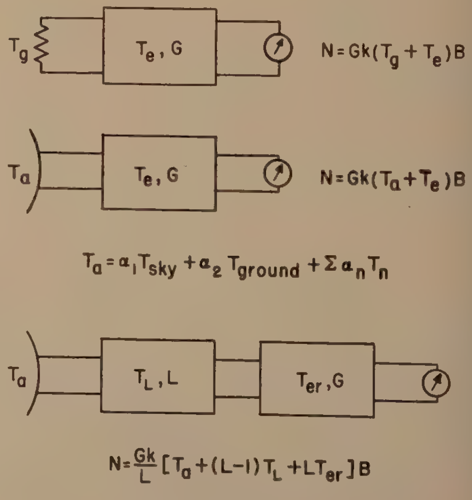
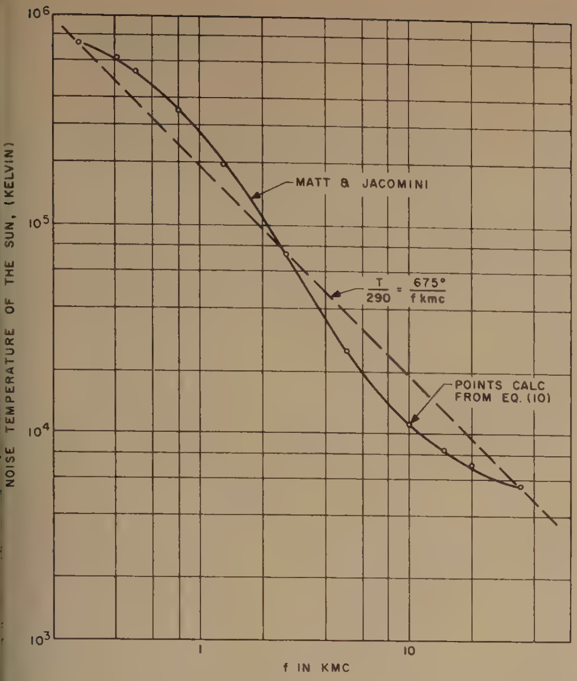

T_g
T_e, G
N=Gk(T_g+T_e)B
T_a
T_e, G
N=Gk(T_a+T_e)B
T_a=$\alpha_1 T_{sky}$+$\alpha_2 T_{ground}$+$\Sigma \alpha_n T_n$
T_a
T_L, L
T_{er}, G
N=$\frac{Gk}{L}$[T_a+(L−1)T_L+LT_{er}]B

Figure 1 — Block diagrams of Receivers.



ure 2 — Sun noise temperature as a function of frequency.

The equivalent noise temperature of the quiet sun es from about 6000° Kelvin at 30 kmc to 7 (10^5) rees Kelvin at 300 mc. This variation can be expressed he approximate relation:

$$\frac{\mathrm{T\,sun}}{290} = \frac{675}{f} \qquad (9)$$

= temperature in degrees Kelvin
= frequency in kilomegacycles

he departure of the linear relationship expressed in ation (9) from the measured values of sun tempera- is small at 250 mc, 2.5 kmc, and at 35 kmc. How-, at 9 kmc it gives a temperature about 70% too high at 850 mc it gives a temperature about 60% too low. he observed values of sun temperature between 250 acycles and 35 kilomegacycles follow more closely the ion:

$$\frac{\mathrm{sun}}{90} = \frac{675}{f}\left(1 + \frac{1}{2.3}\sin 2\pi\,\frac{\log_{10}6\,(f-0.1)}{2.3}\right) \qquad (10)$$

f = frequency in kilomegacycles

nce the sun subtends a plane angle of about ½°, the erature given by Equation (10) would be observed an antenna whose beam width is not greater than ½° n the beam is directed at the sun. For antennas whose width is greater than ½°, the antenna temperature creased by the square of the beam width with respect e sun's diameter, thus:

$${}_1 = \mathrm{T\,sun}\left(\frac{0.5}{\theta}\right)^2$$

r $\theta \geqq$ ½° (11a)

= plane angle beam width of antenna in degrees
${}_1$ = T sun for $\theta \leqq$ ½° (11b)

r further discussion of the sun's temperature, reference ade to S. Matt and O. J. Jacomini, General Electric nced Electronics Center, Cornell University, Ithaca, N.Y., Report R55ELC8, February 18, 1955. Equation (10) was derived from the data given in that report and agrees with these data within 5% from 250 mc to 35 kmc, as can be seen in Figure 2.

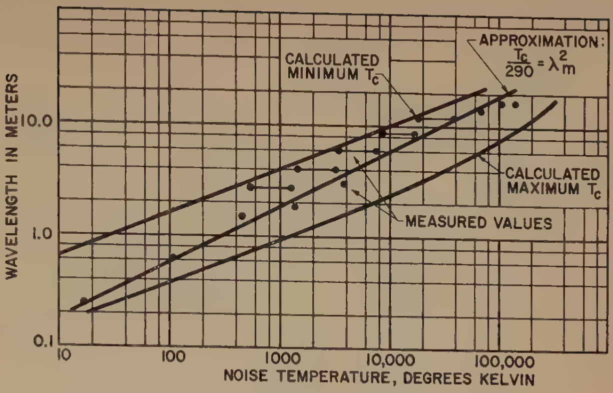


Figure 3 — Measured and Calculated values of sky noise temperature due to galactic sources.

Galactic Noise

Let us now consider the sky temperature due to galactic noise and absorption in the troposphere.

It is of interest to note that, due to cosmic noise, antenna temperatures encountered in practice may be anything up to a few hundred thousand degrees, depending on the wavelength, the antenna directivity, efficiency and orientation.

Mr. K. G. Jansky, of the Bell Telephone Laboratories at Holmdel, N.J., was the first to report quantitative data on cosmic noise. He discovered that it was greatest when his antenna was pointed at the center of our galaxy. His measurements[1] showed that 10 log $\frac{T_a}{290}$ was as high as 25.6 db at a wavelength of 16.7 meters and as high as 23.6 db at 14 meters. Subsequently other workers substantiated Jansky's results and extended the range of measurements to the higher frequencies.

For example, Cottony and Johler[2] made measurements of cosmic noise temperatures in 1948 and 1949 on frequencies from 25 to 110 mc. Their averages of maximum and minimum antenna temperatures observed with a half-wave antenna are given in the following table:

TABLE I

Average Maximum and Minimum Noise Temperatures of Half-Wave Antenna Observed by Cottony and Johler.

Wavelength (*m*)	*Max. T.*	*Min. T.*
12	37,300	17,700
8.58	16,500	8,430
6	7,440	3,470
4	3,160	1,430
2.73	1,230	520

Other observations have been analyzed by Brown and Hazard[3] who have proposed a model of the galaxy which represents satisfactorily the data from surveys which have been made in the range 18.3 to 3000 mc. In their model there are three distinct noise generating regions which must be taken into account:

1) Localized sources within the galaxy
2) Ionized interstellar gas

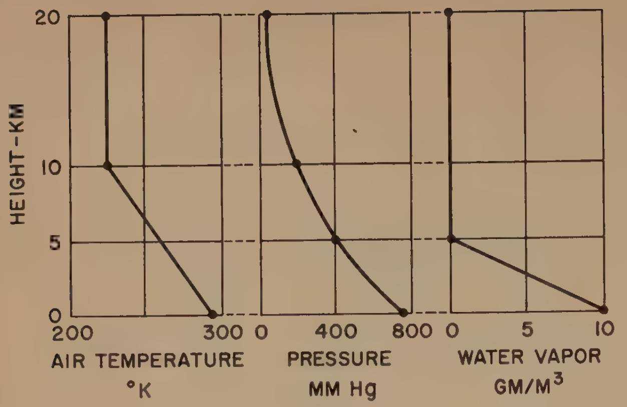


Figure 4 — Summer atmosphere.

3) An isotropic component which may be of extra-galactic origin

They assign values to the contributions of each component and calculate antenna temperatures at several frequencies between 18.3 mc to 3000 mc, where data on observations are available. In making each calculation, the particular antenna beamwidth was taken into account and these ranged from 40° at 18.3 mc to 2.8° at 1200 mc. These calculated and observed values are given in the following table.

TABLE II

Comparison Between the Observed and Calculated Antenna Temperatures in the Direction of the Galactic Center

Wavelength (*m*)	*Calculated* (°*K*)	*Observed* (°*K*)
16.4	141,000	140,000
3.0	3,734	3,860
1.87	1,576	1,370
1.5	456	447
.625	139	107
.25	18.7	17
.1	2	2.6

The agreement between the observed and calculated values leads one to believe that the Brown and Hazard model is reasonably exact. Using this model, these authors then calculated some temperatures for the case of an infinitely narrow beamwidth directed toward the galactic center.

TABLE III

Calculated Temperatures for an Infinitely Narrow Beam Directed Toward the Galactic Center

Wavelength (*m*)	*Calculated Temperature* (°*K*)
16.4	302,150
3.0	18,650
1.87	5,646
1.5	3,155
.625	328
.25	34
.1	4.4

The temperatures given in the above table represent the maximum values that could be observed. The minimum temperatures possible would approach those due to the isotropic component, which, according to the Brown an Hazard model, would be as given in Table IV.

TABLE IV

Calculated Temperature of Isotropic Component Along Line of Sight Neglecting Absorption in Gas

Wavelength (*m*)	*Temperature of Isotropic Component* (°*K*)
16.4	35,000
3.0	500
3.87	150
1.5	90
.625	10
.25	1
.1	0.1

Figure 3 gives a plot of the temperatures quoted in t above tables, together with Jansky's observations. It a pears that the calculated limits of maximum and minimu temperature are reasonable estimates. It is seen that the average sky temperature due to the cosmic noise, given approximately by the following relation, which m be sufficiently accurate for many applications:

$$\frac{T_c}{290} = \lambda^2_m \qquad (1$$

λ_m = wavelength in meters.

In the centimeter range, below 30 cm waveleng $T_c/290$ is so small that it may be neglected. However, the VHF range it cannot be neglected and we should pect the cosmic noise temperature to be within the lim

$$\text{Max } \frac{T_c}{290} = 5\lambda^2_m \qquad (1$$

$$\text{Min } \frac{T_c}{290} = \frac{\lambda^2_m}{5} \qquad (1$$

Noise Due to Tropospheric Absorption

In addition to noise from extra-terrestrial sources, no also originates in the earth's atmosphere because of abso tion of radio waves by oxygen, water vapor and rain. Th

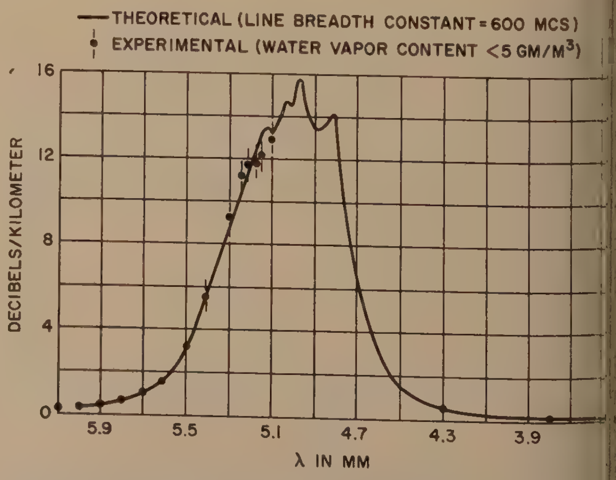


Figure 5 — Absorption of millimeter waves by oxygen standard pressure and temperature.

antenna is surrounded by an absorbing atmosphere that its blackbody radiation. The magnitude of the noise the antenna terminals depends on the absorption co- cient and actual temperature of the atmosphere. Absorp- due to rain will not be dealt with here.

bsorption of radio waves by the atmosphere depends n the temperature, pressure and water vapor content the air. Typical summer conditions that prevail in the 20 km of the atmosphere are shown in Figure 4. temperature decreases linearly by 6.5 degrees per meter to a height of 10 km and then remains constant to 20 km; the pressure and therefore the amount of gen decreases to less than one-tenth of its sea-level e at 20 km height, and the water vapor is assumed lecrease linearly from 10 grams per cubic meter at the h to zero at a height of 5 km.

ormulae for absorption due to oxygen and water vapor been derived by Van Vleck[4] and these formulae been used throughout the calculations to be discussed .

ttenuation by oxygen is due mainly to a strong set absorption lines in the 4-6 mm wavelength region; ulated[5] and observed[6] values of this absorption are vn in Figure 5. The tails or skirts of the absorption s extend through the longer radio wavelengths, the th of the lines and therefore the magnitude of the rption at longer radio wavelengths being determined collisions between molecules. This line broadening is ified by a line-breadth constant which must be de- ined experimentally. As shown in Figure 5, theory es with measurement if a value of about 600 mc is for the line-breadth constant at atmospheric pressure. theory, attenuation by water vapor at radio fre- cies is broken down into two parts: that due to the and absorption line (1.35 cm) and a background ab- tion due to tails of the strong infra-red absorption . A theoretical curve of absorption by water vapor tmospheric pressure for an assumed line-breadth con- of 3 kmc is shown in Figure 6. Again, however, line breadth constants must be determined experi- tally. The K-band line has been measured in the ratory at Columbia University,[7] resulting in a broaden- constant of 3 kmc at atmospheric pressure (Figure 6).

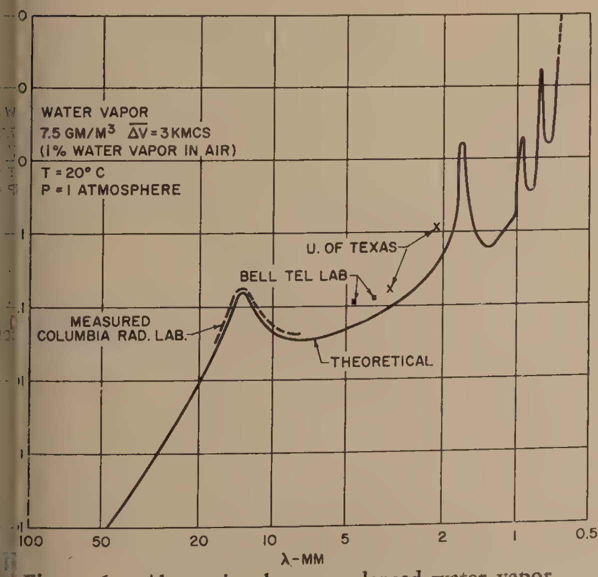


Figure 6 — Absorption by uncondensed water vapor.

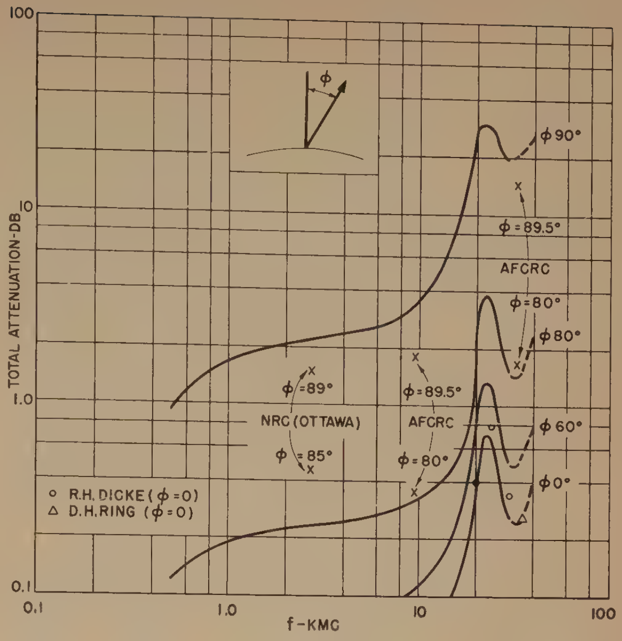


Figure 7 — One-way attenuation through the atmosphere due to oxygen and water vapor (Summer conditions).

On the other hand, outdoor measurements at short millimeter wavelengths, such as those made by the University of Texas[8] (Figure 6) indicate a significantly higher value of about 9 kmc for the broadening constant of the infrared absorption lines.

These measured values of oxygen and water-vapor line-breadth constants have been used in the Van Vleck theory to calculate total attenuation through the atmosphere using the appropriate temperature, pressure and water vapor dependences shown in Figure 4. The resulting attenuation curves are shown in Figure 7 in the frequency range 0.5 to 40 kmc for various values of ψ, the zenith angle of the antenna beam. Since the antenna beam looks through much more atmosphere when pointing along the horizon than when pointing at zenith, the attenuation is much larger at $\psi = 90°$ than at $\psi = 0°$.

There are several measurements of attenuation through the entire atmosphere that can be used to check the calculated curves. In Figure 7, the measured values surrounding the K-band line were obtained by R. H. Dicke et al[9] for $\psi = 0$ during the month of April in their original experiments using the radiometer for measurement of sky temperature. The point at 35 kmc ($\psi = 0$) was obtained by D. H. Ring during the course of sky temperature studies on a classified project; this point is an average of his summertime measurements. The remainder of the data shown were obtained from measurements of the temperature of the sun; the points at 9.5 and 33 kmc are summertime values published by the Air Force Cambridge Research Center[10] and the data at 2.7 kmc were measured at the National Research Council of Canada.[11]

We conclude from the satisfactory agreement between the measured and calculated attenuation data that our knowledge of atmospheric absorption is reasonably accurate and that we therefore may proceed to calculate antenna temperatures on this basis.

The tropospheric contribution to the noise temperature

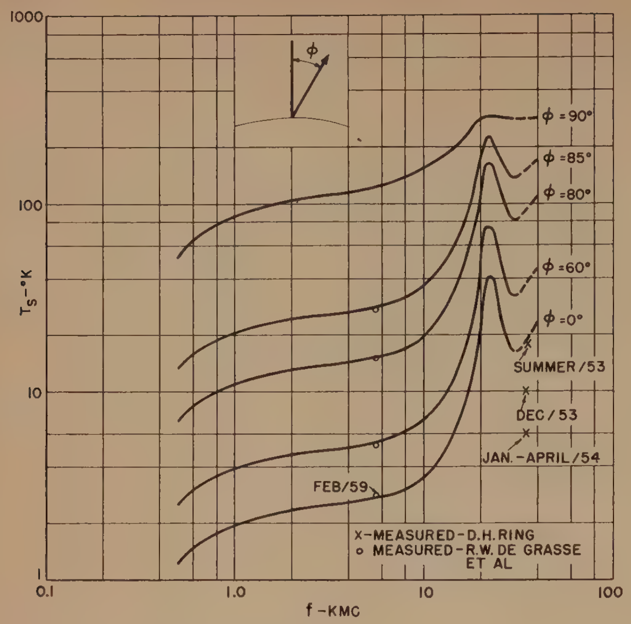


Figure 8 — Sky noise temperature due to oxygen and water vapor (Summer conditions).

of a narrow-beam antenna whose radiation pattern admits no side or back lobes is given by

$$T_s = \int_0^\infty \alpha T e^{-\int_0^r \alpha \, dr} dr \qquad (15)$$

where α and T are the absorption coefficients and temperature of the air at any point in the atmosphere a distance r from the antenna. Calculated curves of T_s for the atmosphere of Figure 4 are shown in Figure 8 with zenith angle ψ as parameter. Note that at the higher frequencies when the antenna beam is pointed along the horizon ($\psi = 90°$) into a strongly absorbing medium, the antenna temperature approaches the actual temperature of the air, 290°.

Measurements of antenna temperature due to the atmosphere are sparse, due mainly to the fact that antennas with exceptionally low side and back lobe patterns are necessary in order to eliminate noise caused by radiation from the earth.

Antenna temperatures measured by D. H. Ring at 35 kmc ($\psi = 0$) are shown in Figure 8; these are corrected data in that Ring determined experimentally the radiation from the ground into the back lobes of his antenna and corrected for it. The average of the summertime measurements agrees well with the calculated value whereas the winter antenna temperatures are lower, presumably due to the reduced water vapor content of the air during winter.

Data have been obtained recently at 6 kmc using a travelling-wave maser amplifier and a horn-reflector type antenna.[12] This combination permitted direct measurement of sky noise since the noise temperature of the amplifier was low (10° K) and the antenna noise due to radiation from the earth was small (1° K). The data are shown on Figure 8 for angles $\psi = 0$, 60, 80 and 85 degrees. At 6 kmc, water vapor in the air contributes only a small amount to the sky noise, therefore the data shown would not change radically from summer to winter as they do at 35 kmc.

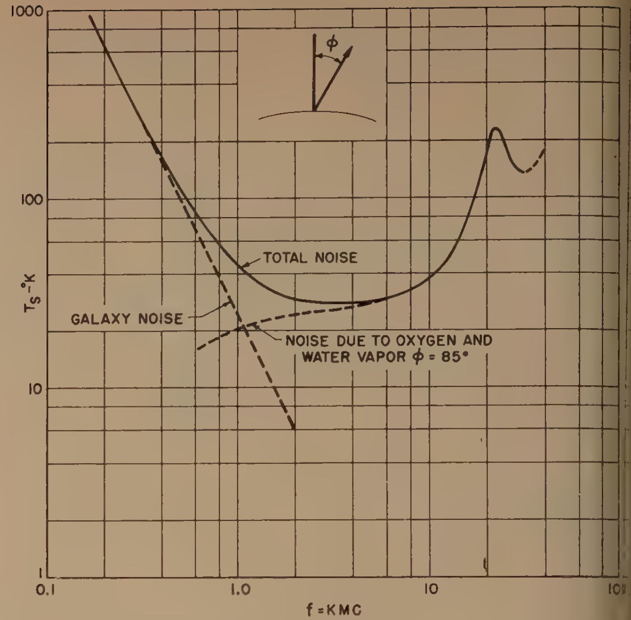


Figure 9 — Sky noise temperature due to atmospheric abso
tion and galactic sources.

Let us now apply the results of our study to a speci problem. Assume that a high gain antenna is to be us for a radar or a satellite transmission system, that t antenna at times will be required to point down to with 5 degrees of the horizon ($\psi = 85°$) and that receiv with very low equivalent temperatures (T_e, say, less th 30° K) are available. What is the optimum operati frequency? The curve for galaxy noise (Figure 3) a the curve for noise due to absorption in the troposph ($\psi = 85°$, Figure 8) have been reproduced in Figure A composite curve has been drawn which has a br minimum between 2 and 6 kmc. As far as antenna te perature is concerned, one therefore concludes that f quencies in the neighborhood of 4 kmc are most suita for the assumed system. However, if the anticipated eff of absorption by rain on antenna temperature is kept mind, one would favor the lower end of the 2-6 kmc ba

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ANTENNA MEASUREMENTS

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PART II

CHAPTER III

EQUIPMENT

nal Sources

ignal Source requirements are discussed in Chapter II.
els of from 0 to + 20 dbm, or from 1 mw to 100 mw,
common in practice.

ackaged signal generators, using conventional tubes,
employed in the lower frequency regions. Generators
his type usually have the following features:

1) Direct frequency calibration,
2) Output level calibration,
3) Precision output attenuation,
4) Flexible modulation capability,
5) Low spurious content in output waveform.

he most widely employed signal source for making
nna measurements in the microwave region is the re-
klystron; however, the more recently developed back-
d-wave oscillator is gradually coming to the front as a
rowave power source because it is voltage-tunable over
e frequency ranges. Other tubes which find applica-
are the magnetron and the planar triode. A brief dis-
ion of these tubes is presented in the following
ons.

he Microwave Triode. Conventional low frequency
des are limited in their operation to a maximum fre-
ncy of about 1000 megacycles; above this frequency
inductance and electron transit time effects make these
s impracticable. For use in the lower microwave re-
, from 1000 mc to about 4000 mc, special triodes have
designed which have a planar electrode structure to
ide for close spacing of the tube elements and for ex-
ely low lead inductance.[23]

he triode has the advantage that it can be made to op-
from a single low voltage power supply. Further,
output frequency can be made relatively independent
modulating voltages by using these tubes in master-
lator power amplifier circuits with cavity resonators.
frequencies near 1000 megacycles, master-oscillator
er amplifier circuits can be employed satisfactorily.
he frequency is raised, these circuits become imprac-
ble, making use of simple oscillator circuits manda-
The klystron and the backward-wave oscillator ex-
definite advantages over the triode in power output
and ease of tuning in the region above 4000 megacycles.

The Klystron. Packaged klystron signal generators or signal sources are available which cover the various waveguide bands up to about 40 kmc. In addition, universal power supplies are available for operation of separately mounted klystrons; these tubes are available in types covering the spectrum up to about 75 kmc.

There are a number of excellent discussions of the principle of operation of the reflex klystron; [24] a brief summary is given below.

The klystron is a velocity modulation device. A schematic diagram of the tube is shown in Figure 8. The electron beam from the cathode is directed through fine mesh grids of the resonant cavity, and in some tubes a "focus" electrode is provided to control the current through the cavity. The cavity acts to bunch the electrons. The repeller, which is negative with respect to the cathode, provides feedback by reflecting the bunched electron beam so that it passes through the resonant cavity a second time. The phase of the feedback is changed by varying the repeller voltage. If the magnitude of the feedback is sufficient, the tube will oscillate at a frequency [25] for which the total phase shift for successive passages of the bunched stream through the cavity is $(2\pi n - \pi/2)$. Power is extracted from the cavity by a pickup loop or a coupling iris.

Adjustment of the frequency of the reflex klystron over its complete tuning range is usually accomplished by mechanically altering the configuration of the tuning cavity. For each setting of the cavity and for a given beam voltage, there are usually several settings of the repeller voltage which provide maxima of the output power. As the repeller voltage is changed in either direction from the voltage at which maximum power output occurs, the power falls off rapidly until the tube fails to oscillate. The regions of the repeller voltage for which oscillations occur are called *repeller voltage modes.* See Figure 9.

The frequency of oscillation is dependent on the values of the applied voltages as well as the cavity tuning. As the repeller voltage is varied across each mode, the frequency varies over a range of a few percent; the electrical tuning bandwidths of the individual modes are dependent in a complex manner on the loaded Q of the cavity and the operating voltages.[26] The detailed operating characteristics of a particular tube can be obtained from the data and curves available from the manufacturers.

The total mechanical tuning range of the klystron de-

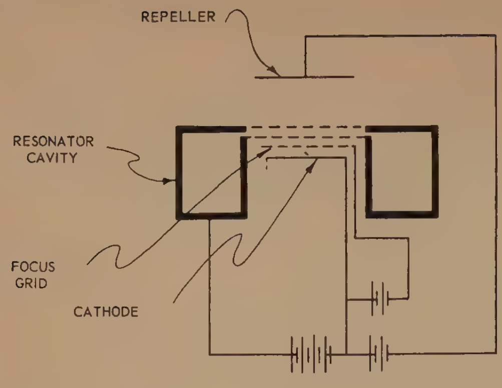


Figure 8 — Schematic diagram of the reflex klystron

pends on the frequency range of the cavity over which the requirements for sustained oscillation can be satisfied. To provide for continuous oscillation as the frequency is varied mechanically, it is necessary to track the repeller voltage as the cavity is adjusted. This feature is provided in most signal generators.

If direct (video) detection of the r-f wave is to be employed, it is necessary to provide modulation of the r-f output. Because of the inherent frequency sensitivity of the klystron to the applied voltages, square-wave modulation is required to prevent frequency modulation (see Figure 9). By application of a square-wave voltage to the repeller, the tube can be driven alternately into and out of a mode of oscillation. If the modulation wave form has zero slope when the klystron is oscillating, frequency modulation of the r-f output will be minimized. This is essential if good resolution of the antenna characteristics as a function of frequency is to be obtained. It is evident from Figure 9 that the modulation amplitude can be such that oscillation is possible on both half-cycles of the modulation; this should be avoided to prevent simultaneous operation at two different frequencies.

Control of the power output of the transmitting klystron is not generally required in making antenna pattern measurements. Where control is required, it may be obtained by the use of waveguide attenuators. Attenuators are usually provided in packaged signal sources.

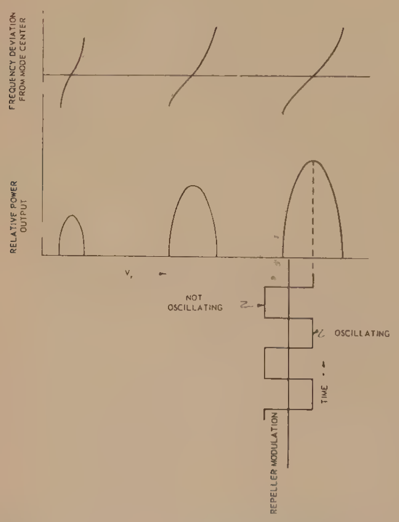


Figure 9 — Klystron repeller voltage modes

The Backward-Wave Oscillator. The backward-wav oscillator is of the traveling wave class of tubes. Detaile discussions of its operation are presented in the literature; [27] a brief description is given below.

The backward-wave oscillator consists basically of a electron gun and a slow wave structure through whic the electron beam from the gun is passed. One possibl structure of this type, which serves to illustrate the principle of operation, is shown in Figure 10.

This slow wave structure is an evacuated waveguid which is arranged in a serpentine path; the electron bea is directed through a series of colinear holes in the structure so that its electrons will react with the field in th guide. The structure has the characteristic that the phas velocity in the guide as seen by a given electron in th beam is in the opposite direction to that of the energ flow down the guide. Let us assume that a wave, whos wavelength is large compared with a single loop of th serpentine, is introduced at the input. The phase velocit V_p, of the wave *as seen by the electron* is defined by

$$V_p = \frac{x}{\lambda_g} V_g, \tag{17}$$

where V_g is the actual phase velocity in the guide, λ_g the guide wavelength, and x is the distance indicated Figure 10. Let the frequency of the input wave be suc that it goes through one complete cycle during the tim that an electron travels the distance x; that is, let t beam velocity be equal to the phase velocity. Under the conditions the electron will be acted upon by simil fields at A, B, and at every other point of interaction. T interaction causes bunching of the electrons as in a klystr or conventional traveling wave tube amplifier; the ele trons that are in a retarding field are pulled back fro their normal positions in the beam and those that are an accelerating field are forced ahead. The resulti bunched beam of electrons, which passes through t holes in the guide in synchronism with the input wa induces a source of radiation at each beam crossing whi radiates down the waveguide in both directions from t beam axis. The wave which radiates in the same dir tion as the input wave, i.e., backward with respect to t beam, reinforces the original bunching action so that t wave intensity increases with distance from the collec end of the structure. The wave that travels *toward* t collector tends to cancel itself, since it becomes progr

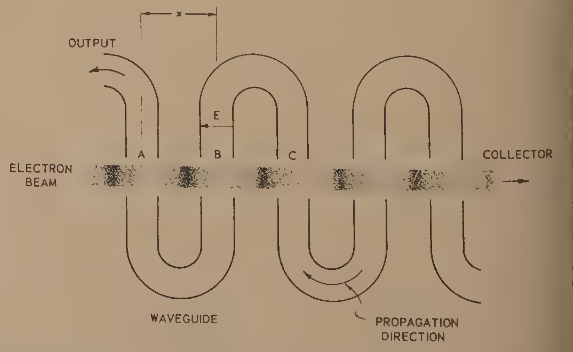


Figure 10 — Basic slow wave structure of backward-w oscillator

ely further out of synchronism with the original wave it proceeds along the waveguide.

While the above discussion was based on amplification an input wave, the amplification of the tube can be de great enough that no input wave is required, and the e acts as an oscillator; perturbations of the electron am are sufficient to set up the required initial bunching on. Variation of the frequency of oscillation of the e is effected by changing the anode voltage, which demines the drift velocity of the electrons. In some backd-wave oscillators the beam is focused along the slow ve structure by means of a permanent magnet which an axially directed field; in others, a solenoid is emyed.[p]

Care must be taken when using the backward-wave llator to provide extremely stable operating voltages that excessive frequency modulation of the output will prevented. As a source of power for making antenna asurements, this type of signal source is useful since it be remotely voltage-tuned and does not require menical adjustment. Backward-wave oscillators are avail to cover the frequency range from 1 to 75 kmc; y have output powers between a few milliwatts and eral watts.

he Magnetron. The principle of operation of the magron is well known and is described in the literature.[28] ile magnetrons find application as signal sources in anna measurements, their usefulness is somewhat limited two factors. Most magnetrons are designed to deliver e peak powers under pulsed conditions so that only raction of the power is contained in the fundamental the pulse repetition frequency, and most magnetrons fixed tuned. On the other hand, there are cw magrons and tunable magnetrons available for operation number of frequencies. A check of the manufacturers' logs will indicate the frequencies for which they are lable. For direct detection of the signal from the ed magnetron, the bolometer is recommended because its nearly square law characteristic and because it is integrating detector, tending to enhance the fundantal frequency component of the output signal.

ectors

he two types of detectors commonly used for making nna measurements are the crystal detector and the ometer. The crystal detector acts to convert the high uency signal to dc and to detect the impressed moduon waveform by the process of rectification. The bolom is a thermo-resistive detector. It consists of a fine wire ch changes in resistance when subjected to electronetic radiation because of the resultant change in perature of the wire.

etectors are non-linear devices. Over a portion of their ating range their transfer law may be represented by

$$V_{out} = kV^{p}_{in}. \qquad (18)$$

practical significance of the exponent p is evident by mination of the logarithmic form of the transfer law. If N_{in} is the number of db equivalent to a certain input voltage *ratio,* and N_{out} is the corresponding number of db change in the output circuit, the transfer law may be expressed

$$N_{out} = pN_{in}. \qquad (19)$$

In the special case where $p = 2$, the number of db of signal variation observed in the output circuit will be exactly twice the number observed in the input circuit. In making measurements with a non-linear device such as a crystal or bolometer detector, it is essential to know and to take into account its transfer law. Of particular importance is the fact that the transfer law tends to vary with V_{in}; thus, the number of db observed in the output circuit for a given change in the input level may not be constant with signal level. Antenna pattern recorder charts are usually calibrated on the assumption that p equals 2; that is, that the detector has a constant square law characteristic. It will be seen that the bolometer has a nearly square law characteristic over a wider dynamic range than does the crystal detector.

Crystal Detector. The crystal detector is a semi-conductor, usually made of silicon or germanium. It is mounted to provide for efficient transfer of the electromagnetic energy to the crystal element. The crystal element consists of the semi-conductor material and a pointed tungsten wire, or cat whisker. The wire is brought into contact with the crystal with a controlled pressure, which largely determines the resistance, capacity, and power handling capability of the crystal.[29]

The transfer characteristic of the crystal is non-linear and unilateral, resulting in rectification of the radio frequency range. Modulation of the input wave is detected in the output circuit. For the case of the crystal, the exponent p in equation (18) varies from about 2 at signal levels of the order of 1/4 microwatt to approximately 1 at levels of the order of 1 milliwatt.[q] The dynamic range over which the crystal has a nearly constant square law characteristic ($p = 2$) is determined largely by how small a signal can be detected in the presence of noise. This is determined by the type crystal and the bandwidth of the system. Essentially square law operation over a dynamic range of 25 to 30 db is common using audio bandwidths of the order of 50 cps. Larger dynamic ranges can be achieved by employing narrower bandwidths to decrease the minimum detectable signal level. However, this imposes more stringent stability requirements on the audio modulation and filter frequencies, and in the limit, measuring speed is sacrificed because the bandwidth determines the rate at which the system can respond to modulation changes.

Important crystal parameters in addition to the detection law are the *dynamic impedance* and the *detection sensitivity.* At low signal levels the crystal detector can be considered a constant current source shunted by its dynamic impedance.

The detection sensitivity of a crystal is given in terms of the *figure of merit* of the crystal and the *minimum detectable signal* in the equation

$$\frac{V_s}{V_n} = \frac{P}{\sqrt{4kT\triangle f}} M, \qquad (20)$$

---

[p] In this discussion the slow wave structure is pictured waveguide; actually, it can be any type of periodic cture which has the characteristic that the phase veloc is opposite to the direction of energy flow. The helix ch a structure, and it is used in most backward-wave llators.

[q] At intermediate levels p may go as high as 3, depending on the load impedance.

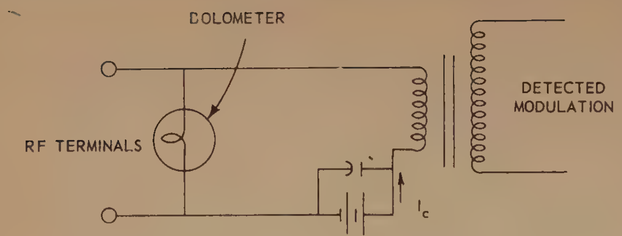


Figure 11 — Basic bolometer detector circuit

where .

V_s/V_n is the ratio of the output signal voltage to the output noise voltage,

P is the input signal power to the crystal,

$4KT = 1.6 \times 10^{-20}$ watts/cycle,

$\triangle f$ is the audio bandwidth, and

M is the figure of merit of the crystal in its operating circuit[30]

M is found to lie generally between 50 and 100 for good crystals. For $V_s/V_n = 1$, $\triangle f = 100$, and $M = 50$ cycles, the minimum detectable signal is found to be 2.5 x 10^{-11} watts. In practice, especially at microwave frequencies, minimum detectable signal levels are considerably higher than this because of the difficulty of directing all of the input power to flow through the crystal element. Typical minimum detectable signal levels are of the order of minus 60 dbm for bandwidths of 50 to 100 cps. In the millimeter wave region the minimum detectable signal level is still poorer.

The Bolometer Detector. The bolometer, or more specifically the barreter,[r] is an extremely fine wire, usually of platinum, with a diameter which may be less than 10^{-5} inch. It functions as a detector of electromagnetic energy by means of its change in electrical resistance as it heats up from the incident radiation. By making the cross section of the bolometer very small, it can be made with a thermal time constant as low as about 100 microseconds.

In operation as a detector in the circuit of Figure 11, a dc biasing current, I_c, is passed through the transformer primary to the bolometer, and the r-f signal is impressed on the wire. When the element is heated by the r-f energy, its resistance increases and causes a change in the dc current through the bolometer and transformer. For a bolometer with a 100 microsecond time constant, the resistance varies significantly with modulation frequencies up to a few kilocycles. The operating modulation frequency is often set at 1 kc.

The typical bolometer has a detection law which is very nearly square for input signal levels less than about 200 microwatts.[31] Essentially square law operation over a dynamic range of 40 db is typical for audio bandwidths of the order of 50 cps.

A disadvantage of the bolometer is its relatively poor detection sensitivity. Bolometers are typically 15 db less sensitive than crystal detectors except in the millimeter wave region, where the crystal loses sensitivity because its series inductance and shunt capacity reduce the curren through the crystal.

In summary, both the crystal and bolometer are simpl direct detectors of r-f energy, but each suffers from deficiencies. The crystal does not have a good square law characteristic except under limited conditions; the bolometer, while exhibiting a good square law characteristi over a wide dynamic range, is limited by its poor detection sensitivity. Both devices have poor detection sensitivities in comparison with that of the superheterodyne receiver. In spite of their deficiencies both crystal and bolometer detectors are widely used as direct detectors i laboratory measurements.

Wide Range Superheterodyne Receiving System. Th principal advantages of the superheterodyne receiver ar two: (1) it has a much higher detection efficiency tha the direct detector, and (2) it maintains a relatively constant gain and selectivity over its full tuning range. Ther are many complete discussions of the superheterodyn principle and receiver in the literature.[32]

As a receiver for use in precise antenna measuremen on the other hand, the conventional superheterodyne ha several disadvantages:

(1) It does not have either a wide linear or a wid square law dynamic range.

(2) It requires a complex r-f head for coverage of wide frequency range.

(3) Slight frequency drift of the local oscillator, eve with AFC, can cause appreciable change in gai while measurements are being made, with resulta errors in the data.

(4) The AFC circuits of conventional receivers a capable of operating over only a small portion the dynamic range encountered in antenna patter measurements.

(5) At microwave frequencies the r-f head must b mounted on or close to the antenna to prevent excessive lead-in loss.

A Wide Range Receiving System has been designed specifically for use in making precise antenna pattern measur ments, and the above disadvantages of the conventiona superheterodyne are eliminated. This receiver is of pa ticular value where greater sensitivity and linear dynam range are required than that obtainable by direct detectio with the crystal or bolometer. An increase in sensitivi of from 25 to 35 db over that obtainable with a cryst detector is typical if limiting bandwidths are equal.

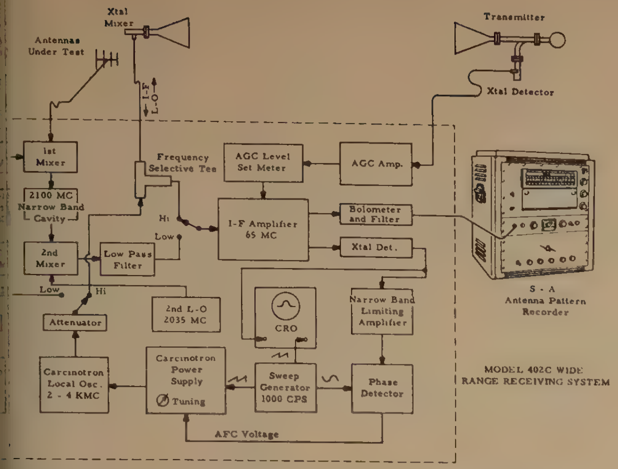
A functional diagram is given in Figure 13. Th operation of this receiver is described.

A backward-wave oscillator,[s] voltage-tunable over t frequency range of 2 kmc to 4 kmc, serves as the loc oscillator. For receiver operation between 2 kmc and kmc, the oscillator signal is fed through a coaxial ca to a simple crystal mixer at the terminals of the anten under test. The local oscillator is tuned such that its f

---

[r] Barreters and thermistors are types of bolometers. The thermistor is a small bead of semi-conducting material supported between two wires. It acts as a resistor with a large negative temperature coefficient. Its time constant is much larger than that of the barreter, and it is commonly used for average power level measurements.

[s] The backward-wave oscillator was developed in Fra under the name "Carcinotron." The tube employed in receiver is the Type QKB691; it is manufactured by R theon under license from the Compagnie Generale Telegraphie Sans Fil (CSF).



igure 13 — Functional diagram of the receiving system

ncy, or one of its harmonics generated by the crystal,
erodynes with the received signal to provide an inter-
liate frequency of 65 mc. This i-f signal, whose ampli-
e is proportional to that of the received signal, is re-
hed through the same coaxial cable to the i-f amplifier.
e the coaxial cable connecting the receiver and the
tal mixer carries only the 65 mc i-f signal and the
damental component of the high power local oscillator
ial, the receiver and mixer may be separated by as much
75 feet with negligible effect on the sensitivity of the
em.

he backward-wave oscillator is swept in frequency at
000 cps rate over a range of several megacycles. When
gnal is received, the heterodyne mixer output is swept
ugh the pass band of the i-f amplifier with a sweep-
th somewhat greater than the i-f bandwidth. The re-
ing audio modulation of the i-f signal is detected by
olometer, and the detected signal is fed to an antenna
ern recorder or other indicating device.

n additional local oscillator and mixer circuit is used
receiver coverage between 30 mc and 2 kmc. The in-
ing signal is heterodyned with the backward-wave
illator frequency to produce a 2100 mc signal in the
mixer. A narrow band cavity between the first and
nd mixers prevents spurious signals from entering the
iver. A 2035 mc second local oscillator frequency is
rodyned with the 2100 mc frequency in the second
er to produce the 65 mc i-f frequency.

he backward-wave oscillator center frequency is tuned
he desired value by adjusting the delay line voltage
means of a coarse and fine voltage control. A volt-
er and a frequency-versus-voltage tuning chart are pro-
d for initial receiver frequency settings. A cathode-ray
lloscope display of the i-f output is provided to facili-
initial adjustments in local oscillator frequency, sweep
hs, and AFC action. A crystal detector is used to
ide a signal for the cathode ray oscilloscope and the
circuit.

weeping of the local oscillator makes the receiver
ost completely insensitive to drifts of the transmitter
local oscillator frequencies as long as the received
al is included within the swept frequency interval.
AFC system which operates over the full dynamic
e of the receiver prevents detuning for larger fre-
ncy drifts. AFC action is obtained by comparing the
e of the backward-wave oscillator sweep voltage to
that of the i-f crystal detector video output. When the received signal or the local oscillator signal drifts, the error signal from the phase detector is added to the backward-wave oscillator dc tuning voltage to shift the center frequency of the oscillator. Positive lock-in action is maintained at all signal levels from receiver saturation to noise.

The AGC circuit provided in the receiver consists of a stable dc feedback amplifier, gain controls, and an AGC Set-Point meter. A sample of the transmitter signal is detected by a crystal. The output of the AGC Amplifier is used to control the gain of the i-f amplifier to compensate for transmitter power variations over a range of ± 2 db.

Although the receiver is designed primarily for the reception of cw signals, square-wave modulation may be employed. In this case, the transmitter modulation frequency and the receiver sweep frequency must differ such that the resulting beat frequency is greater than the response frequency of the recorder. No r-f preselection is provided other than that of the bandpass characteristics of the antenna and the r-f system under test, although an external tunable filter may be placed in the r-f system for additional interference rejection if required. Either of the two image responses may be selected for operation; the AFC operates on either.

Pattern Recorders

It is almost essential that automatic recording equipment be employed in making antenna measurements. Manual pattern recording is impracticable because of the amount of data required to provide adequate determination of the fine structure of a pattern.

Characteristics which are of primary importance in the selection of an antenna pattern recorder are:

(1) sensitivity
(2) accuracy of the pen and chart responses
(3) writing speed
(4) reliability
(5) versatility
(6) ease of maintenance
(7) cost.

As was discussed previously, the antenna under test can be operated on transmission or reception. In either case the received signal is detected and automatically plotted by a recorder whose chart position can be synchronized with the orientation of either axis of the positioner.

The recorder may have a polar or rectangular chart. The polar recorder is often used in plotting patterns of antennas which are not highly directional because this type of presentation gives a physical picture of the transmitted power in space. The rectangular recorder permits narrow patterns to be recorded in much finer detail because the pattern does not become crowded in regions of low intensity as it does on the polar graph. The rectangular recorder is therefore normally used for measuring patterns of narrow-beam antennas. To provide for the display of patterns of various beamwidths with adequate resolution, the ratio between the chart motion and antenna rotation is made adjustable in steps.

The pen deflection of either the polar or rectangular recorder can be made proportional to the amplitude or to the power of the received signal, or to the signal level in decibels. The amplitude of the signal is proportional to $h(\theta,\phi)$ of equation (3); the power is proportional to the gain $g(\theta,\phi)$ of equation (7). In measurements on microwave antennas a wide range of power levels is encountered because of the high order of side lobe suppression attainable. It is therefore convenient to record the signal in decibels since the logarithmic scale magnifies the low level signals.[t]

Microwave Antenna Test Equipment

Figure 15 is a drawing of a microwave antenna test range. Considerations which are important in setting up the range, choosing the proper separation between antennas, etc., are discussed in Chapter II. In the following paragraphs typical equipment for instrumenting the range is discussed.

Receiving Site. In the pictured test range, as in most, antennas under test are operated on receiving. In the typical test site the antenna positioner is mounted on a tower, and the control, receiving and recording equipment is located in an instrument room situated conveniently near the positioner site, often in a room directly below.

The calibrated attenuator is required in making gain measurements and in checking the linearity of the system.[u] Precise linearity over wide dynamic ranges is difficult to achieve. Crystal detectors are notoriously poor in this respect; if quantitative measurements are required over a range of more than about 30 db, it is usually necessary to take into account the variation of the detection characteristic of the crystal. Bolometers are somewhat better in this respect than are crystals; however, it should not be tacitly assumed that they have a true square law detection characteristic if precise measurements are required over a wide dynamic range. The S-A Series 402 Receivers have a dynamic range which is linear within ± 1 db over a 40 db range; this range is extended to 60 db in one variation in which a potentiometer in the recorder is employed to control the bias of the receiver i-f amplifier. Additionally a calibrated i-f step attenuator can be obtained in the Series 402 receivers for use in attenuation and gain measurements and in checking system linearity.

The boresight telescope and the field monitor horn ar both of value in testing narrow beam antennas. The boresight telescope is often required in adjusting the axis o the beam to coincide with a specified mechanical axis. In any event, it is helpful to make a preliminary boresigh alignment at short range where a large signal level i available; this can eliminate sometimes frustrating and time-consuming searches for the beam at full range separation between antennas. This is true whether using direct detection or the Series 402 Receiver. In the forme case, there is never any extra signal; in the latter, there i the necessity of tuning the receiver to the transmitter frequency. This is, of course, impossible if the test antenn is far off axis and happens to be oriented so that a dee null is facing the transmitting antenna.

The field monitor horn is shown connected to a cryst detector through a directly calibrated absorption frequenc meter. The detector is connected to a Signal Level Monit to monitor the transmitter signal level and frequency. Th unit is a special purpose high sensitivity ac or dc vacuum tube voltmeter; it is thus capable of operating from modulated or unmodulated carrier. Sensitivity of the un is approximately 500 microvolts full scale. This permi operation from a typical X-band crystal detector with r-f input signal level of about —40 dbm. Equatio (10a) can be employed to calculate the gain required o the field monitor horn. If the required gain makes th use of a field monitor horn impracticable, the frequenc meter can be connected to the antenna under test an observed with the Receiver.

The Model 402C Receiver has provision for automati gain control to compensate for variation of the transmitt power level over a range of ±2 db. If sufficient gain available from the field monitor horn, this signal can b

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[t] See Decibels, Chapter II.

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[u] See Detectors, pp. 87-89.

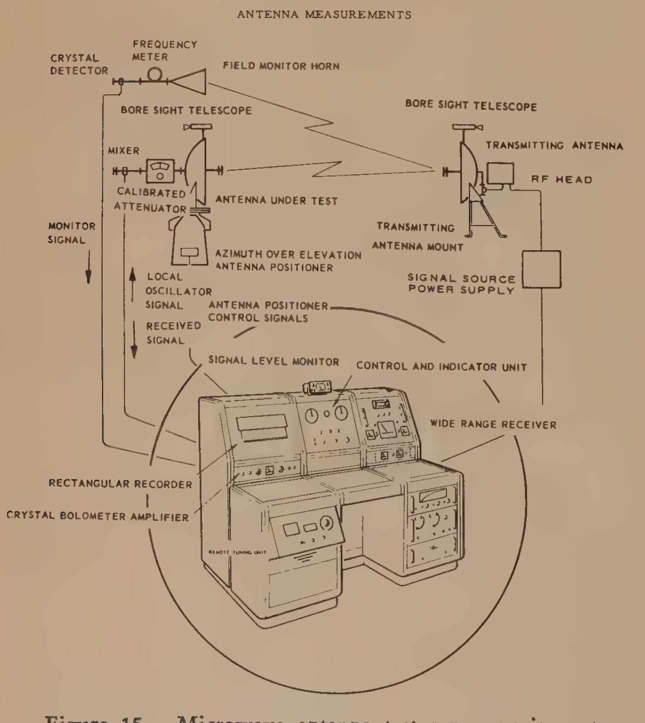
ANTENNA MEASUREMENTS
CRYSTAL DETECTOR
FREQUENCY METER
FIELD MONITOR HORN
BORE SIGHT TELESCOPE
BORE SIGHT TELESCOPE
TRANSMITTING ANTENNA
MIXER
RF HEAD
CALIBRATED ATTENUATOR
ANTENNA UNDER TEST
MONITOR SIGNAL
TRANSMITTING ANTENNA MOUNT
AZIMUTH OVER ELEVATION ANTENNA POSITIONER
LOCAL OSCILLATOR SIGNAL
SIGNAL SOURCE POWER SUPPLY
ANTENNA POSITIONER CONTROL SIGNALS
RECEIVED SIGNAL
SIGNAL LEVEL MONITOR
CONTROL AND INDICATOR UNIT
WIDE RANGE RECEIVER
RECTANGULAR RECORDER
CRYSTAL BOLOMETER AMPLIFIER
REMOTE TUNING UNIT

Figure 15 — Microwave antenna test range equipment

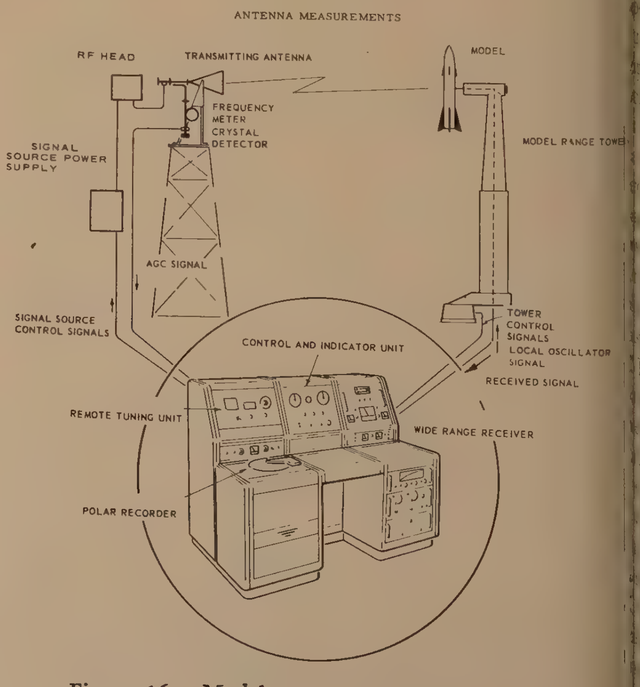
ANTENNA MEASUREMENTS
RF HEAD
TRANSMITTING ANTENNA
MODEL
FREQUENCY METER
CRYSTAL DETECTOR
SIGNAL SOURCE POWER SUPPLY
MODEL RANGE TOWE
AGC SIGNAL
SIGNAL SOURCE CONTROL SIGNALS
TOWER CONTROL SIGNALS
LOCAL OSCILLATOR SIGNAL
CONTROL AND INDICATOR UNIT
RECEIVED SIGNAL
REMOTE TUNING UNIT
WIDE RANGE RECEIVER
POLAR RECORDER

Figure 16 — Model antenna test range equipment

nployed to operate the AGC circuit. Otherwise, the GC signal can be obtained from a directional coupler the transmitter as shown in Figure 16.

Transmitting Site. The transmitting equipment is lo-ed on a tower or roof top at a distance from the receiv- site that satisfies the aperture phase requirements of apter II. It may be helpful, depending on the environ-nt, if the transmitting equipment can be made secure d protected from the weather without having to disturb or to change the orientation of the antenna.

The antenna must have the required polarization char-eristics and should have sufficient gain to satisfy equa-n (10a) for the dynamic range over which it is neces-y to make measurements. To limit the measuring error a reasonable value, the transmitting antenna and receiv-g antenna dimensions should satisfy equation (15).

The transmitting antenna should be located on a mount ich is adjustable about two orthogonal axes for directing beam maximum toward the receiving antenna. A bore-ht telescope, which has been aligned with the beam max-num at short range, may save time in making the initial gnment.

The signal source is typically a klystron or backward-ve oscillator or possibly a magnetron. The backward-ve oscillator source has the advantage that it can be ctronically controlled from the test sight. The power pply required depends on the type signal source that is ployed. Universal supplies are commercially available operation of klystrons of virtually all types. The back-rd-wave oscillator requires a highly stabilized supply to vent undesired frequency modulation of the output ve.

del Antenna Range Equipment

definition of the model antenna is given in Part I. brief discussion of measurements of the characteristics this type of antenna is given in Chapter IV, with refer-es to the literature. Figure 16 represents a model an-na test range.

The heart of the model antenna test facility is the model er. Measurements made must simulate as accurately as sible the characteristics of the model antenna when it is removed from the ground. The tower should be able of supporting a model weighing up to about 200 nds but must interfere with the electromagnetic field little as practicable. Shown schematically in Figure 16 typical Tower with an 8-foot extension section, which vides an over-all tower height of 16 feet. Above the e, the tower is constructed entirely of materials with dielectric constants. Honeycomb radome type con-ction is employed in the supporting structure to pro-e a maximum of rigidity and strength with minimum ortion of the electromagnetic field.

The problem of achieving adequate measuring sensi-ty is inherently difficult in making model measure-nts. The transmitting antenna must be sufficiently small the separation between the transmitting antenna and model must be great enough to provide a field over entire model which is nearly uniform in amplitude phase. In addition, the gain of the model antenna is erently low.

One of the problems in making model antenna measure-nts is that of bringing the coaxial signal lead away m the model without excessive interference with the tern of the model antenna. The coaxial lead should be brought out opposite to the test antenna to provide as much shielding as possible by the model. It should be maintained normal to the incident E field until it is as far from the model as possible. Figure 16 shows the coax going through the tower to the base. It may be desirable in some cases to extend it horizontally to the rear of the tower.

A crystal detector and frequency meter are shown coupled to the input terminals of the transmitting antenna for monitoring the signal level and frequency.

Equipment for Ground Plane Antenna Measurements

A schematic drawing of a ground plane antenna test range is shown in Figure 17. The antenna under test and the operating frequency are scaled as discussed under Model Antenna Measurements of Chapter IV. The antenna is mounted in the ground plane on a removable flush turntable.

The antenna is usually tested on transmission; the transmitting equipment is mounted on a platform which rotates with the turntable and is supplied power through slip rings. The receiving antenna is linearly polarized. It is mounted on an arm that can be positioned about a horizontal axis (A) passing through the antenna under test. This is equivalent to rotation of the turntable about axis A of Figure 5. As in testing microwave and model antennas, ϕ cuts are made by rotation of the turntable about its own axis. Cuts in θ are made by rotation of the arm which supports the sampling antenna.

Provision is usually made for rotation of the sampling antenna through 360 degrees about its own axis to permit obtaining patterns for any two desired orthogonal polarizations. Sometimes the sampling antenna is rotated about this axis at a speed which is fast compared with the rotation through θ or ϕ but within the writing speed of the recorder. The θ or ϕ pattern will then have serrations produced by the rotation of the sampling antenna. The ratio of the amplitudes of the two patterns indicated by the envelope of the serrations is the polarization ratio. See Polarization Measurements, Chapter IV. To determine the orientation of the polarization ellipse, it is necessary to know the orientation of the sampling antenna with respect to the serrations of the pattern.

CHAPTER IV

MEASUREMENTS

The basic antenna measurements are described in the following sections. Gain, directivity, efficiency, antenna patterns, polarization, and phase measurements are included. The sections are generally brief since reliance is placed on the prior material and on the references.

Gain

The gain of an antenna was defined in Chapter I. In practice the maximum gain is usually the quantity that is measured; the gain in any direction can be determined from the maximum gain and the radiation pattern of the antenna. The maximum gain is usually measured by comparison with a standard gain antenna. The calibration of standard gain antennas is described elsewhere[34] and will not be discussed here.

In the comparison method the antenna under test is usually operated on reception as shown in Figure 18. The line to the detector must be matched, either with a matching device or by padding, to give a flat line looking to the left at line AA. If the range of the precision attenuator is sufficient, it can also serve as a pad.

The antenna under test is adjusted in azimuth and elevation until the received power is maximum. This assures that the maximum of the beam is pointing toward the transmitting antenna. The attenuator is adjusted to give a convenient reading on the indicator, and the attenuator setting is recorded. The antenna under test is then replaced by the standard antenna, and the attenuator is readjusted to give the original indicator reading. During the comparison the transmitted power and the indicator gain must remain constant.

The gain of the antenna in db is given by

$$G = G_s + A - A_s, \tag{21}$$

where $A - A_s$ is the difference in the attenuator settings in db and G_s is the gain of the standard antenna.[v]

Directivity and Efficiency

The directivity, $d(\theta,\phi)$, was defined in Chapter I; it is also called the directive gain and the directivity function. The directivity of an antenna is related to the gain by the antenna efficiency, η:

$$d(\theta,\phi) = \frac{g(\theta,\phi)}{\eta} \tag{7a}$$

To measure the antenna efficiency, independent measurements must be made of d and g for the same values of θ and ϕ. Usually, η is determined by the ratio of the maximum gain to the maximum directivity.

The directivity expresses the distribution of the radiated power in space:

$$d(\theta,\phi) = \frac{\Phi(\theta,\phi)}{P_t/4\pi}. \tag{5}$$

This can be written

$$d(\theta,\phi) = \frac{\Phi(\theta,\phi)}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} \Phi(\theta,\phi)\ \sin\theta\ d\theta\ d\phi} \tag{5a}$$

Thus, it is necessary to integrate $\Phi(\theta,\phi)$ over the complete sphere or any parts that receive appreciable powe to determine the directivity. An approximation to th integral of (5a) can be obtained graphically after taking a representative number of pattern cuts. This is tedious however, and pattern integrators have been develope which perform the integration automatically. Several type have been developed using ball and disk integrators o electronic integrators. The S-A Model API-1 series o antenna pattern integrators are digital readout instrument The readout consists of two numbers, N_1 and N_2; N_1 i proportional to the denominator of (5a) and N_2 is proportional to Φ for a selected direction θ, ϕ. The value o N_2 is determined by electronically multiplying a calibration constant by a voltage which is proportional to Φ This gives

$$d(\theta,\phi) = \frac{N_2}{N_1}. \tag{5b}$$

Antenna Patterns

The far-zone pattern of an antenna describes, for transmitting antenna, the distribution of the transmitte energy in space and, for a receiving antenna, the relativ sensitivity of the antenna to waves approaching from an direction. The radiation pattern and the receiving patter are identical in shape in accordance with the reciprocit theorem; therefore, the measurement of either suffices. Th detail that is required in measuring the antenna patter depends on the anticipated use of the antenna. A complet description requires measurement of the polarization ellipse, including the amplitude, shape, orientation, an sense of the ellipse at each point on the surface of sphere of large radius centered on the antenna. For antennas that are designed to be linearly polarized, it is usually sufficient to measure the pattern for two orthogonal polarizations, the desired polarization and the cross polarization.

In determining the pattern of omnidirectional antenna it is necessary to make ϕ cuts for a sufficient number o fixed values of θ, or vice versa, to describe the patter adequately; these cuts are often made while integrating th power pattern to determine the directivity.

In measuring the pattern of narrow beam antennas, principal plane patterns (see Pattern Range Coordinate Part I) for orthogonal polarizations may provide sufficient information.

Siting Considerations are discussed in Chapter II, an test equipment for use in making pattern measuremen is discussed in Chapter III.

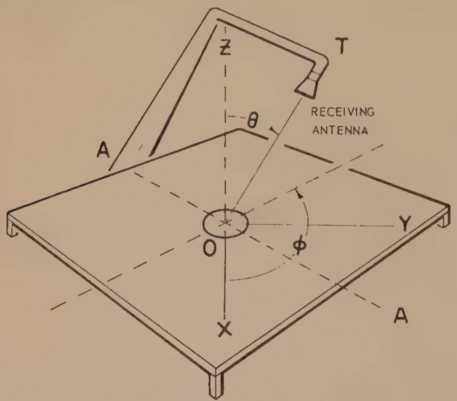

Figure 17 — Schematic drawing of a ground plane test range

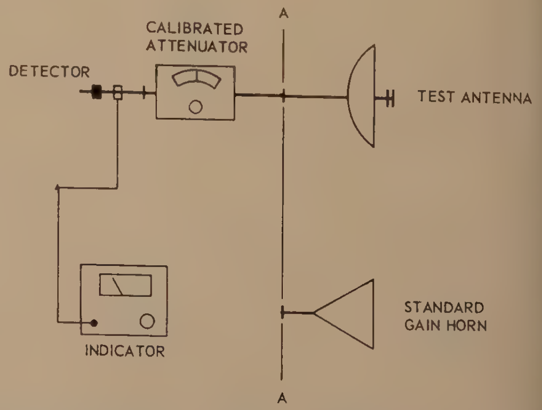

Figure 18 — Setup for measuring antenna gain by the comparison method

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[v] It is here assumed that the antenna under test is matched to the transmission line. If it is a low loss antenna, the effect of mismatch can be taken into account by adding $[10 \log (1 + \text{VSWR})^2/4\ \text{VSWR}]$ to the measured gain, where the VSWR is measured looking into the antenna on transmission.

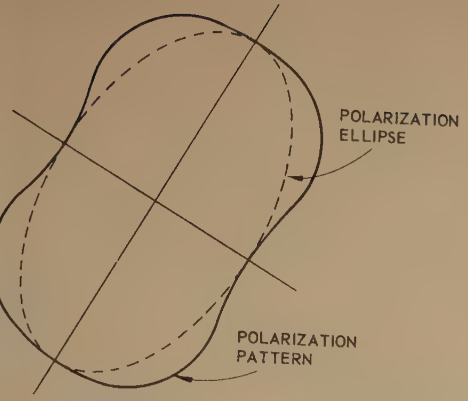

Figure 19 — Polarization pattern and polarization ellipse

arization

it is necessary to determine the *shape* and *orientation* of polarization ellipse and the *sense* of rotation of the E tor to completely describe the polarization of the field duced by an antenna in a given direction. Three meth- are commonly employed for making these measure- nts.[35] These are summarized below.

Polarization Pattern Method. In this method a lin- ly polarized sampling antenna is rotated in a plane ich is normal to the direction of propagation. The field ensity observed at each orientation is proportional to amplitude of the E field parallel to the sampling an- na. A graph of the measured field does not describe polarization ellipse but the *polarization pattern.* Figure shows a typical polarization pattern and the correspond- polarization ellipse which can be constructed from the arization pattern. This measurement determines the pe and orientation of the polarization ellipse, but does determine the sense of rotation; this can be determined in method 3 below.

Linear Component Method. Two linearly polarized ennas are mounted perpendicular to each other and to direction of propagation. From the ratio of the fields asured by the two antennas and from the relative phase ween them, the polarization ellipse can be constructed the sense of rotation determined.[36]

Circular Component Method. In this method two ularly polarized antennas of opposite sense are em- yed to sample the field; oppositely wound helical an- nas are often employed. The ratio of the right-handed the left-handed circularly polarized wave and the rela- phase between the two completely describe the polari- ion characteristics of the wave.[37] The ratio suffices determine the sense of rotation for method 1.

put Impedance

The input impedance of antennas in the UHF and her ranges is commonly measured by determining the e of mismatch the antenna produces when connected a transmission line. Measurement of the standing wave io and the distance from the antenna terminals to a tage or current minimum on the transmission line per- s determination of the input impedance of the antenna means of the Smith Chart.[38]

At lower frequencies where slotted line sections for asuring the standing wave ratio would be too large to practicable, an impedance bridge can be employed to asure the impedance.

ase

Measurement of the relative phase over the far-zone pattern of antennas is usually not required. However, measurement of the phase of the far-zone patterns of small antennas that are employed as primary feeds for secondary radiators is often necessary. This is required to permit determination of the effective center of phase of the antenna so that it can be located at the focus of the secondary radiator. In addition, phase measurements are at times made over the aperture of an antenna in making adjustments or so that its far-zone radiation pattern can be calculated.[39]

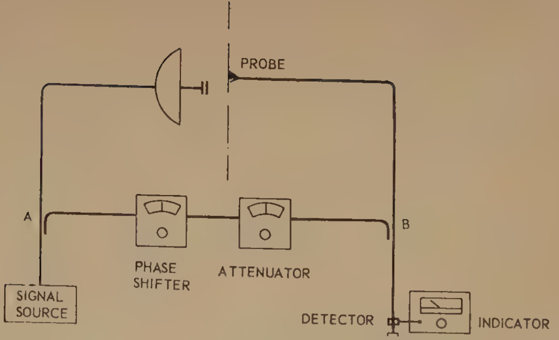

Figure 20 — Setup for measuring phase of field in an antenna aperture

A setup such as that shown schematically in Figure 20 can be employed to measure phase.[40] The probe is moved in a selected path, and the phase shifter and attenuator are adjusted to maintain a null at the detector between the transmitted signal and the reference signal. The reference signal and transmitted signal path lengths should be as nearly as possible equal between points A and B to keep the measurements from being extremely sensitive to small frequency changes.

Model Antenna Measurements

Equipment for making model measurements is discussed in Chapter III. The theory of models of electromagnetic systems is given by Sinclair,[41] and a discussion of antenna pattern measuring techniques using models is given by Sinclair, Jordan, and Vaughan.[42] It is suggested that both of these references be read before attempting to obtain quantitative data from model antenna measurements.

Symbols

CHAPTER III

v_p phase velocity of an electron stream.
v_g guide phase velocity
λ_g guide wavelength.
p exponent in a detector transfer function.
M figure of merit of a crystal.
k Boltzmann's constant (1.371×10^{-23} watt sec/deg).
T temperature in degrees Kelvin.
$\triangle f$ bandwidth, cps.

Equations

The following is a list of equations which are used frequently in antenna calculations and measurements. Numbers in parentheses refer to numbers of the corresponding equations in the text. Unless indicated, the symbols are those in the List of Symbols in Parts I and II.

A. DIRECTIVITY AND GAIN

1. Gain in terms of effective area:

$$g(\theta, \phi) = \frac{4\pi A(\theta, \phi)}{\lambda^2} \qquad (9a)$$

2. Gain in terms of efficiency and directivity:
$$g(\theta,\phi)=\eta d(\theta,\phi) \qquad (7)$$

3. Maximum gain of a pencil-beam antenna, where θ_1 and θ_2 are half-power beamwidths in two orthogonal planes:
$$g_{max}=\frac{30{,}000}{\theta_1\,\theta_2}$$

4. Gain of lossless isotropic radiator:
$$g=1$$
$$G=0 \text{ db}$$

5. Maximum gain of a lossless half-wave dipole:
$$g_{max}=1.64$$
$$G_{max}=2.15 \text{ db}$$

B. SITING

1. Range at which phase deviation at edges of linear aperture is $\lambda/16$:
$$R=\frac{2d^2}{\lambda}$$

2. Recommended separation between antennas for far-zone measurements:
$$R=\frac{(d_1+d_2)^2}{\lambda} \qquad (15)$$

3. Height, h_2, of first maximum of interference pattern between direct and ground reflected waves, where h_1 is height of transmitting antenna[w]:
$$h_2=\frac{\lambda R}{4h_1}$$

C. BEAMWIDTH

1. Approximate half-power beamwidth of narrow beam antenna:
$$\theta \doteq \frac{70\,\lambda}{d}$$

2. Approximate half-power beamwidth of pencil-bea antenna:
$$\theta \doteq \sqrt{\frac{30{,}000}{g_{max}}}$$

D. POWER TRANSMISSION

1. One-way power transmission equation:
$$P_r=P_o\left(\frac{\lambda}{4\pi R}\right)^2 g(\theta,\phi)\,g'(\theta',\phi')$$
(10

2. One-way power transmission equation in db:
$$L_r=L_o+G(\theta,\phi)+G'(\theta',\phi')-20\log\left(\frac{4\pi R}{\lambda}\right)$$
(10a

3. Radar equation, where σ is the radar cross section a target:
$$P_r=P_o\frac{\lambda^2}{(4\pi)^3R^4}\,g^2(\theta,\phi)\,\sigma$$

E. NOISE

1. Boltzmann's constant: $k=1.38 \times 10^{-23}$ watt sec/de

2. Thermal mean square noise voltage generated by resistance, R:
$$\ddot{e}_n{}^2=4kTR\triangle f$$

3. Thermal noise power generated by a resistance, R:
$$P_n=4kT\triangle f$$
$$P_n=1.65 \times 10^{-20}\triangle f \times \frac{T}{300} \text{ watt-sec.}$$

4. Thermal noise level *generated by* a resistance of:
$$L=-108 \text{ dbm}+10\log\frac{\triangle f}{10^6}+10\log\frac{T}{300}$$

5. Thermal noise level *available to a matched load* acro a resistance R:
$$L=-114 \text{ dbm}+10\log\frac{\triangle f}{10^6}+10\log\frac{T}{300}$$

---

[w] For a complete discussion of the applicability of this equation, see Jordan (Reference 10 of the Bibliography) pp. 609-635.

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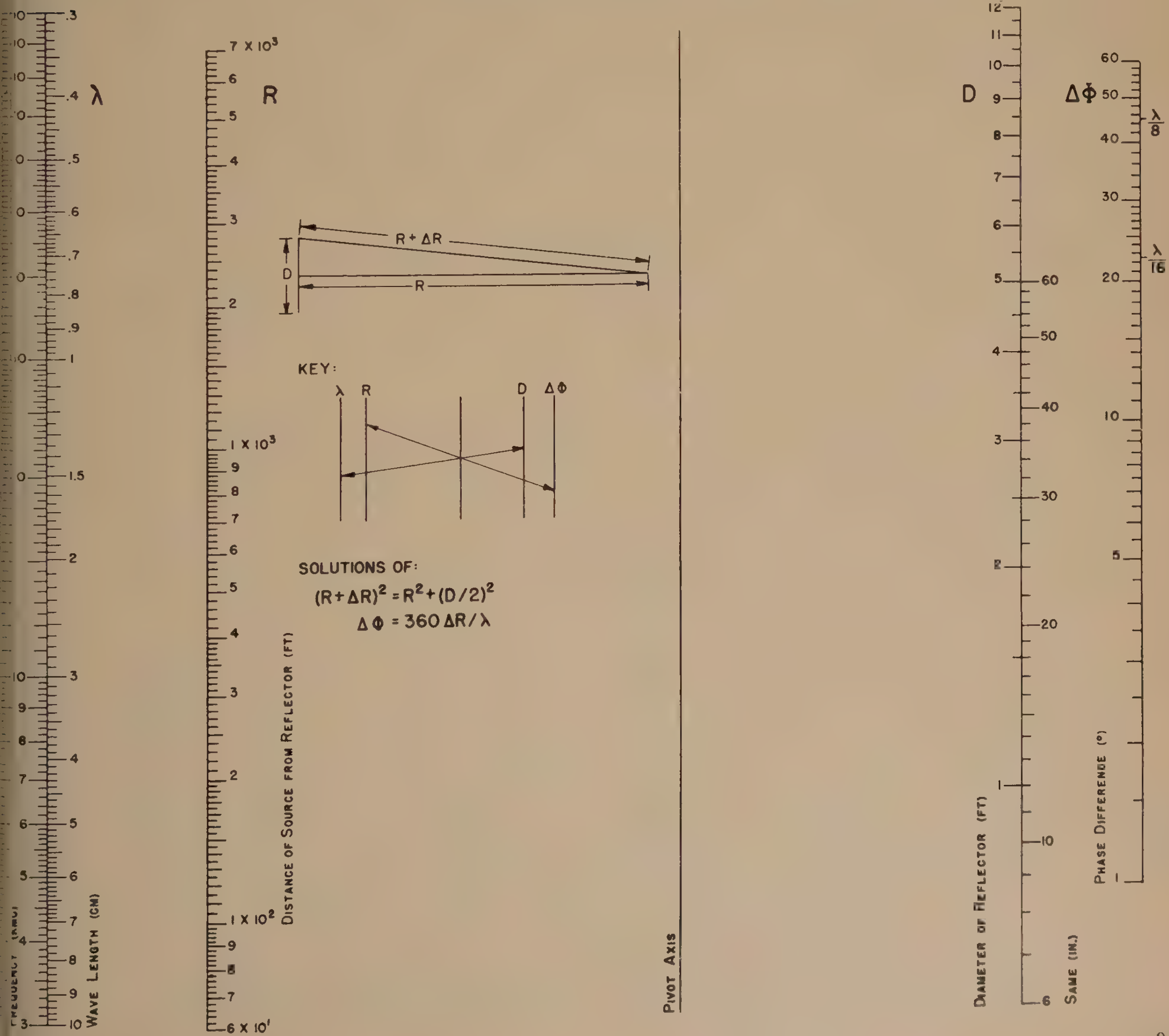
NOMOGRAPHS

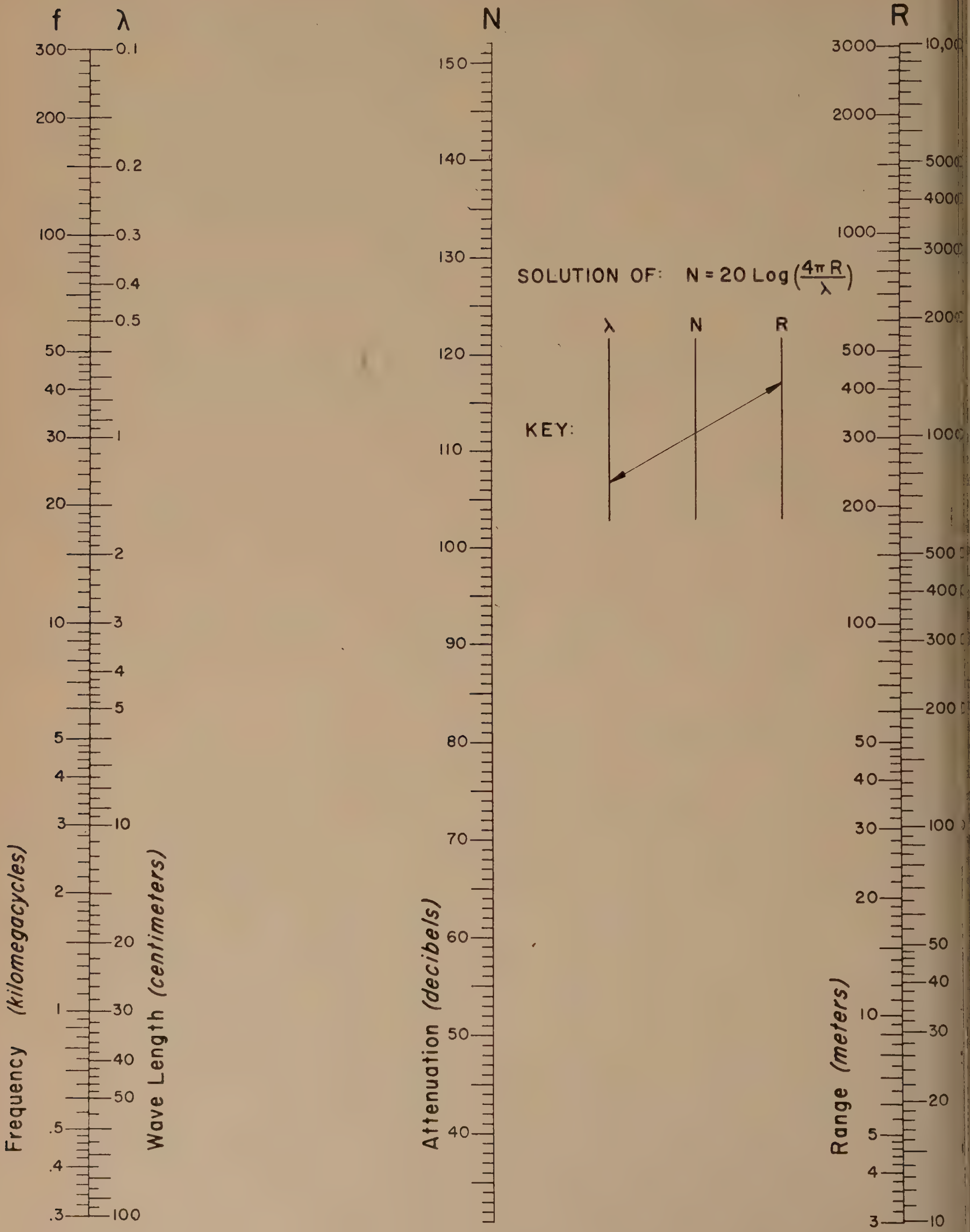
NOMOGRAPH OF PHASE DEVIATION AT EDGES OF LINEAR APERTURE AS A FUNCTION OF SEPARATION BETWEEN ANTENNAS

If the nomograph does not cover the desired range of λ, R and D, multiply all three scales by n, and multiply $\triangle\phi$ scale by unity.



NOMOGRAPH OF SPACE ATTENUATION AS A FUNCTION OF RANGE

If the nomograph does not cover the desired range of λ and R, multiply both scales by n, and multiply N scale by unity



NOVEL APPLICATIONS of the SMITH CHART

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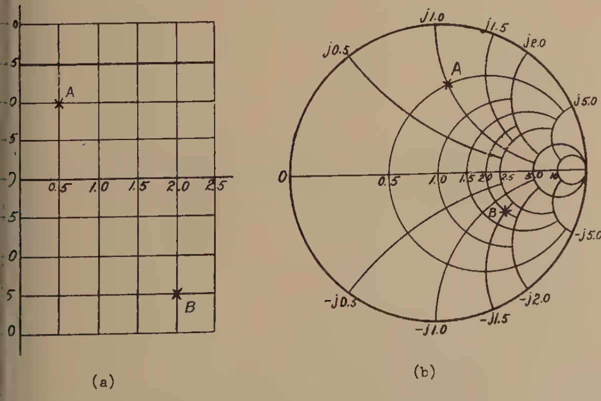
earlier issues of *the microwave journal* there have ap- ed several interesting articles on the application of Smith chart for microwave calculations, as well as two esting articles concerning its originator, Mr. P. H. h.[1]

addition to the use of the chart for finding the usual tities, such as impedance or admittance, reflection fac- etc., the chart proves quite useful in other ways. These r uses may have little or no connection with transmis- lines or allied equipment.

the first place, as was pointed out by Dr. Southworth ne of the references cited, the familiar Smith chart is ly a conformal transformation of the cartesian coordi- system. Only the first and fourth quadrants are gen- y used, but the chart may be rotated 180° to represent second and third quadrants.

Figure 1, the point *A* is plotted at (0.5 + j1) on chart while point *B* appears at (2—j1.5). The num- of points which can be represented on the chart in ure 1(a) is limited to those having a real part of 2.5 ess and an imaginary part of ± 2 or less. On the th chart of Figure 1(b) all points from zero to infinity be shown. The Smith chart may be thought of as a plot on a plane of the cartesian coordinate system as it would appear if it were drawn on the surface of a sphere of infinite radius. Although such a comparison is crude, at best, it is quite helpful in the visualization process. Figure 2(a) indicates the general idea for the (x + jy)-plane, and the two Smith charts placed "back-to-back" in Figure 2(b) represent the entire surface area of the sphere. Notice that all values of x and y, from zero to ± ∞, may be plotted on the finite-size chart in Figure 2(b).



(a) (b)

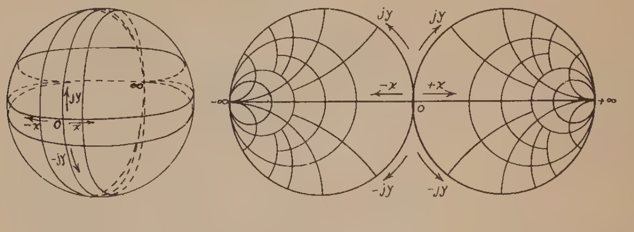
ure 1 — Comparison of cartesian coordinates with Smith-chart coordinates.

One simple example which will illustrate the point being made here is shown in Figure 3. This is not to say that the plot in Figure 3(b) is any better, or even as good for some uses, as that in Figure 3(a). Nevertheless, the general idea is worth considering for any type of plot. Of course, impedance, admittance, or any other complex quantity can be represented equally well.

Because the Smith chart includes all possible points from zero to infinity, it may be used to plot the variation of functions other than those dealing with energy propagation. Any two-dimensional plot may be shown. All of these will have a somewhat different appearance than when plotted on the coordinate system generally associated with them, as shown in Figure 3. Some of these plots will prove both novel and useful in their new form.

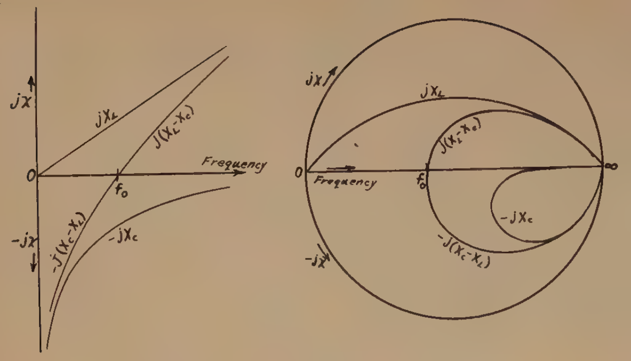
Hyperbolic Functions of Real Numbers

The hyperbolic functions of real numbers are generally found in tables which are readily available and may be



(a) (b)

Figure 2 — Representation of how two Smith-charts can represent the entire surface area of a sphere.



(a) (b)

Figure 3 — Curves representing the variation of reactance as frequency varies for a series connected inductor and capacitor.

had to quite a high degree of accuracy. The hyperbolic functions are defined as follows:

$$\sinh x = \tfrac{1}{2}\left(e^{x} - e^{-x}\right) \tag{1}$$

$$\cosh x = \tfrac{1}{2}\left(e^{x} + e^{-x}\right) \tag{2}$$

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} = \frac{1 - e^{-2x}}{1 + e^{-2x}} \tag{3}$$

If tables of hyperbolic functions are not at hand, tables of e^{x} and e^{-x} are often available. If slide rule accuracy is sufficient, it is little trouble to calculate the function using the common log-log slide rule, or the power series representation is quite useful and accurate. Hence the plots of the hyberbolic functions shown in Figure 4 are not offered as a replacement of tables of functions, but as a form of visualization of the possibilities of utilizing the geometry of the Smith chart. The cosh curve on the Smith chart seems to be discontinuous at $a = 0$, but if reference is made to Figure 2(a) again it will be seen that it is continuous through the point corresponding to $y = 1$.

Hyperbolic Functions of Complex Numbers

While hyperbolic functions of real numbers are rather easily obtained as mentioned in the previous section, obtaining the value of a hyperbolic function of a complex number is considerably more tedious. The usual forms f hyperbolic functions of complex numbers are

$$\sinh(a + jb) = \sinh a \cos b + j \cosh a \sin b \qquad (4$$

$$\cosh(a + jb) = \cosh a \cos b + j \sinh a \sin b \qquad (5$$

$$\tanh(a + jb) = \frac{\sinh a \cos b + j \cosh a \sin b}{\cosh a \cos b + j \sinh a \sin b}$$

(6

Or polar notation may be used, and letting the x in (1 (2) and (3) equal $(a + jb)$, we obtain

$$\sinh(a + jb) = \tfrac{1}{2}\left(e^{a}\underline{/b} - e^{-a}\underline{/-b}\right) \qquad (7$$

$$\cosh(a + jb) = \tfrac{1}{2}\left(e^{a}\underline{/b} + e^{-a}\underline{/-b}\right) \qquad (8$$

$$\tanh(a + jb) = \frac{e^{a}\underline{/b} - e^{-a}\underline{/-b}}{e^{a}\underline{/b} + e^{-a}\underline{/-b}} = \frac{1 - e^{2a}\underline{/-2b}}{1 + e^{2a}\underline{/-2}}$$

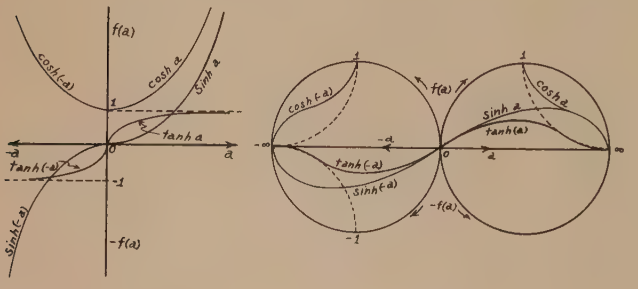
(9

No matter how the calculation is made, the evaluati of the hyperbolic function of a complex number is qui time consuming, at best. Several forms of charts have be designed to allow one to read the complex value of a h perbolic function of a complex number directly from t chart.[2]

The Smith chart was originally designed for reading i pedance or admittance along a transmission line, and sin such values can often be expressed as tanh or coth of complex number, the chart is ideally adapted for su work. Suppose, for example, that

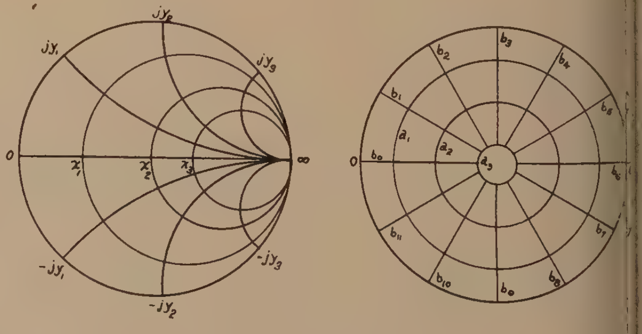
$$\tanh(a + jb) = x + jy \qquad (10$$

where x and y represent the real and imaginary parts the function. The two coordinates of the Smith char may represent either a and b or x and y in (10). Su pose we represent x and y on the Smith-chart coordinat Then different values of *a* are represented by a family circles concentric with the center of the chart. Vario values of *b* are represented by a family of straight lin radiating from the center of the chart. Figure 5 show the general construction. In practice, the two diagrams Figure 5 would be superimposed so that any one poi on the chart could be stated in terms of four coordinate



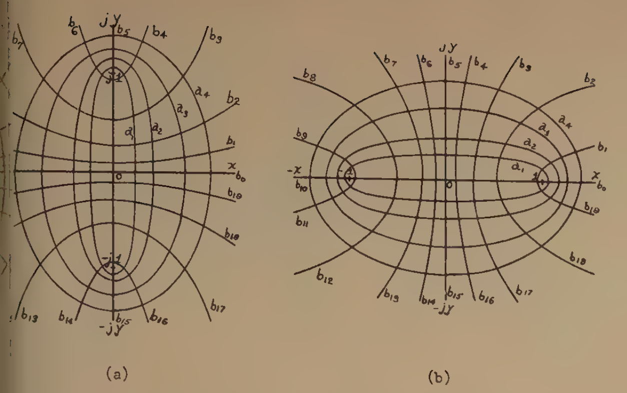
(a) (b)

Figure 4 — Hyperbolic functions of real numbers plotted in (a) cartesian coordinates and (b) Smith-chart coordinates.



(a) (b)

Figure 5 — Standard Smith-chart coordinates and the a-b g to be superimposed upon it to find tanh $(a + jb)$ $x + jy$.



(a)

(b)

ure 6 — Plots of (a) the sinh $(a + jb) = x + jy$ and (b) the cosh $(a + jb) = x + jy$ in cartesian coordinates.

instance, a point might be designated as p (x, y, a, b). point may be located in terms of any two of these variables.

mith charts are available from a number of suppliers he form of graph paper, usually printed with red ink. grid of Figure 5(b) may then be superimposed upon chart, with black drawing ink, and a handy chart anh $(a + jb)$ is obtained. The circles of Figure 5(b) e a radius of e^{-2a} units and the radial lines make an le of 2b radians with respect to the line from 0 to the ter of the chart in Figure 5(a). The radius of the t is to be considered as one unit, so when $a = 0$, $^{(0)} = 1$, and the outer circumference of the Smith t represents $a = 0$. For constant values of a, tanh $+ jb)$ is repetitive every π radians, so values of b n zero to π are sufficient.

ften special expanded Smith charts are available. These ts are useful for plotting tanh $(a + jb)$ for larger es of a than can be obtained with the full chart. Values much greater than 1.0 are difficult to read from the chart because the a-circle becomes so small. If an exded Smith chart covering values along the real axis n 0.64 to 1.58 is available, values of a from 0.8 to ut 2.0 can be read conveniently. On the expanded th chart, its coordinates are approaching rectangular dinates again, because the expansion makes the pors of the circles appear to be almost straight lines.

further expansion is necessary, it is found that a grid, as that in Figure 5(b), can be plotted on standard ar graph paper. For example, suppose a circle 7″ in neter were drawn on standard graph paper and this le were to represent $a = 2$. Then the center of the le would represent unity at the center of the "Smith t." The horizontal axis would cover the range from 0.965 to $x = 1.035$, and the vertical axis from $y =$ $.035$ to $y = + 0.035$. Even though linear graph paper sed, the accuracy is within about 0.1%, for effectively chart would represent the center portion of a Smith rt some 31.8 ft. in diameter.

he values of sinh $(a + jb)$ and cosh $(a + jb)$ can plotted on Smith charts also, but here a point-by-point is necessary. The functions plot as ellipses or hyperas, as is shown in Figure 6, if plotted in cartesian coinates. However, if the same functions are plotted on th charts they appear as in Figure 7 and Figure 8. plots of Figures 7 and 8 are somewhat tedious to make it will be found that the region near the origin is ened up" and fairly easy to read with reasonable accuracy as compared with the same regions in Figures 6(a) and (b). Although the charts look more symmetrical when plotted as in Figure 6, they are actually somewhat more useful when b takes decimal values, such as 0.1, 0.2, . . . For such values of b the hyperbolas are not continuous through the y-axis in Figure 6(a) or the x-axis in Figure 6(b). In both Figures 6(a) and 6(b), as $a \rightarrow \infty$ the ellipses become more nearly circles, since $e^{-a} \rightarrow 0$ and $\sinh(a + jb) \cong \cosh(a + jb) \cong (\frac{1}{2})e^{a}\underline{/b}$. This is the reason that in both Figures 7 and 8 the regions near $\pm \infty$ appear as orthogonal sets of circles and radiating lines.

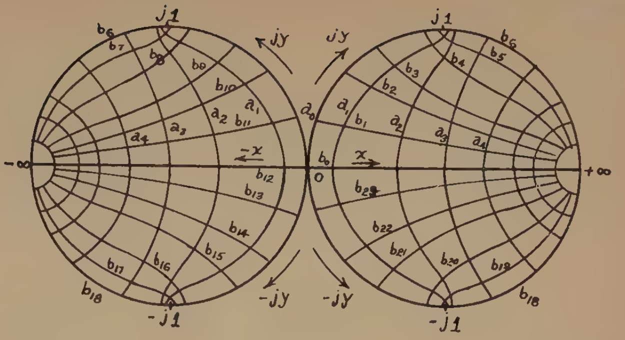


Figure 7 — Plot of sinh $(a + jb) = x + jy$ on Smith-chart coordinates.

Trigonometric Functions

While the trigonometric functions (sine, cosine and tangent) can be plotted directly on Smith-chart coordinates, the result is not very revealing. However, it is of some interest to recall that

$$\sinh(0 + jb) = j \sin b \qquad (11)$$

$$\cosh(0 + jb) = \cos b \qquad (12)$$

$$\tanh(0 + jb) = j \tan b \qquad (13)$$

Now utilizing these relationships, the trigonometric functions may be read directly from the hyperbolic function charts of Figures 7 and 8 simply by letting $a = 0$. As an example, suppose the tan $0.6 =$ tan 34.4° were desired. In Figure 5(b) the radial line $b = 0.6$ strikes the edge of the chart at the value j0.685. Hence from (13), the tan 34.4° = 0.685. In Figure 7 the sin b may be read from the place where the lines of constant b strike the outer circles between 1 and −1. Algebraic signs are automatically correct. The three examples below illustrate the manner of use:

$$\sinh(j0.6) = j0.565$$

$$\sin 0.6 = +0.565 = \sin\ (0.6)\left(\frac{180^\circ}{\pi}\right) = \sin 34.4^\circ$$

$$\sinh(j2.6) = j0.515$$

$$\sin 2.6 = \sin 149^\circ = +0.515$$

$$\sinh(j3.6) = -j0.438$$

$$\sin 3.6 = \sin 206^\circ = -0.438$$

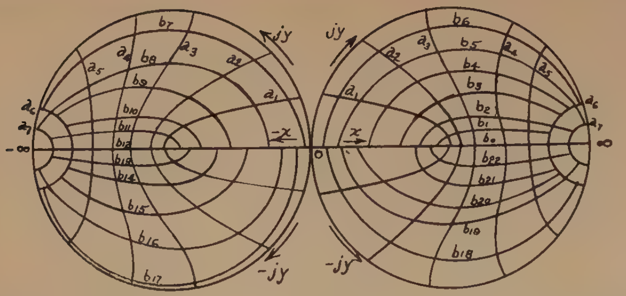


Figure 8 — Plot of cosh $(a + jb) = x + jy$ on Smith-chart coordinates.

In a somewhat similar manner the cosine function may be read from where the lines of constant b strike the horizontal axis between -1 and $+1$. Two examples will suffice here:

$$\cosh j1.2 = 0.358 = \cos 69^\circ$$
$$\cosh j4.4 = -0.309 = \cos 252^\circ$$

Polar Coordinates

Another advantage to be derived from plotting various functions on the Smith chart is that they can so easily be converted to polar form. Many laboratories now have polar forms of the Smith chart printed on clear plastic sheets. These are made the same size as the graph-paper Smith charts and by superimposing the plastic chart over the graph-paper charts a point may be read in either coordinate system. Hence, if the hyperbolic function charts are used with such a plastic overlay, quantities such as the following may be read:

$$\cosh (a + jb) = Z\underline{/\theta} \qquad (14)$$

where Z simply represents the magnitude of the function and θ represents the argument of the function.

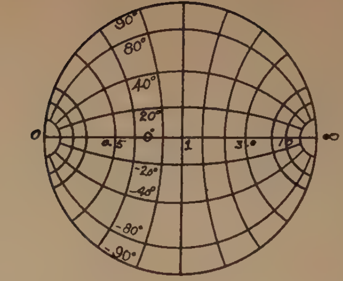


Figure 9 — Polar coordinate form of the Smith-chart.

The polar coordinate Smith charts have the appearance o that of Figure 9. Of course, the normalized form of th Smith chart, in either cartesian coordinates or polar form, will usually be required.

Summary

We have shown how various quantities, complex an simple, may be plotted to some advantage on the Smi chart coordinates. There are many more quantities whic may be used to advantage this way, and only a few of th more common ones have been indicated.

---

1. "Phillip H. Smith," *the microwave journal,* Vol. 1, No. July/Aug., 1958, pp. 44-45; G. C. Southworth, "More Abo Phil Smith — and his diagram," *the microwave journal,* Vo 1, No. 2, Sept./Oct., 1958, pp. 26-28; G. C. Southwo "Using The Smith Diagram - Part I," *the microwave journ* Vol. 2, No. 1, Jan., 1959, pp. 24-31; G. C. Southwort "Using The Smith Diagram - Part II," *the microwa journal,* Vol. 2, No. 2, Feb., 1959, pp. 24-30.
2. For example, A. E. Kennelly, *Chart Atlas of Complex Hype bolic and Circular Functions,* Harvard University Press, Ca bridge, Mass., 1914, 1921, and 1924.

the microwave journal

160 WARREN STREET, BOSTON 19, MASSACHUSETTS
HIghlands 5-6660

Dear Reader:

Each succeeding month *the microwave journal* has increased in size and circulation. This March issue has surpassed even our most optimistic expectations. We are indebted to the entire microwave industry for their confidence and support.

Horizon House, Inc., publisher of *the microwave journal,* has an announcement of interest to make at this time. A magazine devoted to the field of "Solid State" will be published in July 1960. The publication will be named THE SOLID STATE JOURNAL. The first three issues will be bi-monthly. Starting in January 1961, THE SOLID STATE JOURNAL will be published monthly.

The same format and principles will be applied to this publication which have proven so successful with *the microwave journal.* In this manner, we plan to be of service to the solid-state industry as we have been to the microwave industry.

Our efforts will be directed primarily to the applications and techniques of solid-state devices. The fields of interest will include transistors, diodes, infrared, magneto-striction, electro-luminescence, thermo-electricity, cryogenics, plasma phenomenon, etc.

We would like to encourage all authors to submit papers to our editorial office for possible publication in one of our early issues. An honorarium will be paid for accepted papers.

To insure the quality of technical content of THE SOLID STATE JOURNAL we have been fortunate to secure the services of the following well-known men, active in the industry:

1. THEODORE SAAD, President, Sage Laboratories, *Editor*
2. L. P. HUNTER, Manager, Physical Research Dept., IBM Corporation, *Associate Editor*
3. STEVE LEVY, Manager, Commercial Engineering, Philco Corporation, *Associate Editor*
4. ROBERT PRITCHARD, Manager, Device Electronics Branch, Texas Instruments, Inc., *Associate Editor*
5. DONALD O. SMITH, MIT, Lincoln Laboratories, *Associate Editor*
6. LEO E. DWORK, Chief Engineer, Motorola, Inc., *Advisory Board*
7. PROFESSOR HENRY LEVINSTEIN, Syracuse University, *Advisory Board*

A cordial invitation is extended to all our friends both in microwaves and solid state to visit with us at the Essex House, Central Park West, Suite No. 2801, at the IRE Show, March 21-24 in New York. The staff and editors of both publications will be on hand during the hours of the exhibits at the Coliseum.

We are looking forward to your visit.

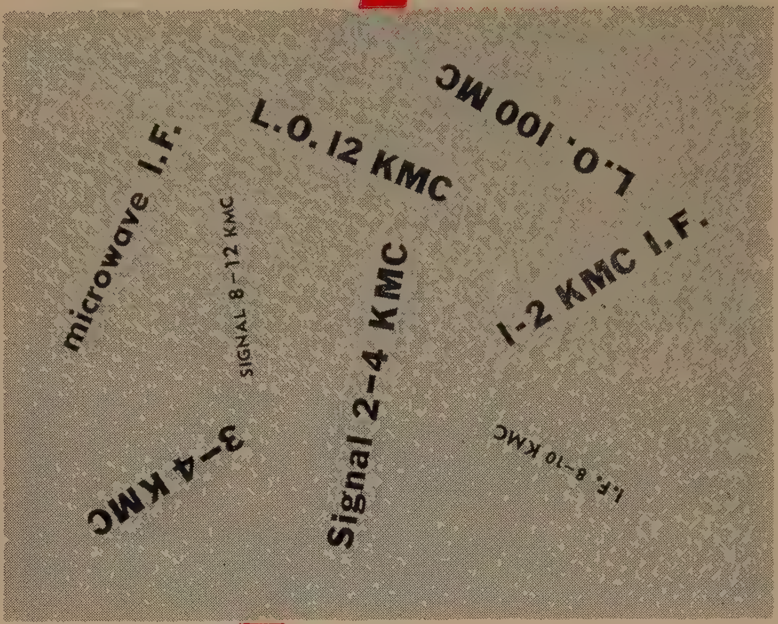
Sincerely,

William Bazzy

Publisher

Ted Saad

Editor



MIXING???

During the past year Sage Laboratories has designed and developed several different types of special mixers.* Many of these have had the I.F. at various frequencies between the VHF region through the X-band. 10 DB conversion loss has been achieved with mixers using an input signal in S-band and an I.F. (with 1 KMC Bandwidth) at X-band. Mixers with a microwave I.F. allow panoramic displays covering thousands of megacycles; other applications for each mixer are:

Countermeasure Systems
Wide Open Receivers
Side Band Generation
Harmonic Generation
Frequency Translation

*Also — years of experience with conventional 30 MC and 60 MC I.F. mixers.

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Contact Sage — we will be happy to quote! or see us at Booth 1910 at the IRE Show.

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SL SAGE laboratories, inc.
3 HURON DRIVE NATICK, MASS.

New Products

(*Continued from page 64*)

A new group of crystal video detect mounts that provide a high tangential sens tivity down to 50 MC were recently d veloped by engineers at American Electron Laboratories, Inc., of Philadelphia, and ha been added to the firm's commercial produc and components line.

Identified as miniature octave band cry tal video detector mounts, they utilize slow wave structure to create a physical short line to match the crystal impedan to the input line. Ranges covered are MC to 120 MC, 120 MC to 300 MC an 300 MC to 600 MC. Tangential sensiti ties better than -55 dbm with selected M 408B or selected IN23B crystals can achieved.

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— *m w j* —

COAXIAL ATTENUATORS FOR HIGH POWER

Coaxial microwave attenuators with input power rating of 15 watts have ju been announced by Microlab of Livingsto New Jersey. This new group of attenuato known as the AD series, operates from D to 4000 mc.

The AD attenuators consist of two more tee section pads properly cascaded distribute the power dissipation. Cooli fins are provided to minimize temperatu rise. Deposited carbon film resistors ceramic forms are used to permit a hi surface temperature with long-term stabil as well as resistance to shock, moisture, e

These attenuators are supplied from sto with N, BNC, TNC, C or HN connecto at values of 3, 6, 10, 20, 30 and 40 Other values can be supplied on requ with delivery generally within two wee The rated frequency range is DC to 40 mc and the input power is 15 watts. Ma mum VSWR is 1.20. They are rugge constructed to meet the environmental co ditions of MIL-E-5272B and other simi specifications.

The AD series attenuators are availa for immediate delivery from stock and priced at $45 to $65 depending upon t attenuation and connectors.

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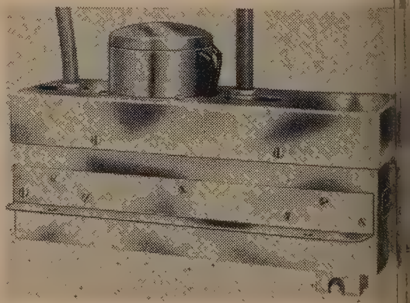
— *m w j* —

MICROWAVE STEP ATTENUATO REMOTELY OPERATED



esigned for use where manual operation
ttenuators is not practical, a new line
or 12-position automatic step attenua-
from Empire Devices is powered by a
or-operated driving mechanism. Actua-
of a simple rotary switch, or of push
ons causes the mechanism to produce,
matically, the rotary and linear move-
ts required to insert the desired attenua-
value.

ypical applications of the new units,
e-marked "Empower," include use in
o-active contaminated areas, on tower
allations, wherever panel space is lim-
or whenever the attenuator must be
ted in an inaccessible part of the equip-
t. They are also recommended for rapid
ching of attenuation values, for pro-
med applications, and for systems
re the voltage sensitivity of a receiver
be automatically determined by pre-
ng signal strength.

Empower" attenuators may be obtained
wide range of standard attenuation
es from 0.1 DB to 60 DB, and capable
andling one or four watts of RF power.
uency range is from DC to 4 KMC,
standard units operate from a 28 VDC
er source. Other voltages will be furn-
on special order.

ttenuators and driving mechanisms are
edly made to provide reliable operation
r extreme service conditions. Conserva-
y rated, the RF characteristics (i.e., im-
ance, attenuation accuracy, etc.) are
tical to Empire's manually operated ver-
s.

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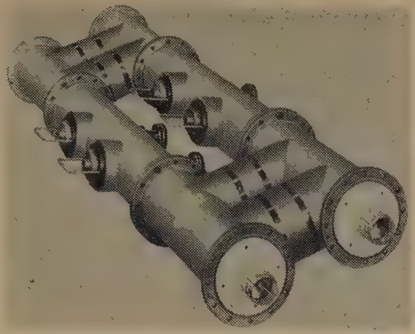
BALANCED COAXIAL LINE DUPLEXER



Bomac Laboratories, Inc., Beverly, Mass. announces a balanced coaxial line duplexer — the BL-595. It consists of two coaxial hybrids and two cavities for "plug-in" cell-type TR tubes. This unit is in 6-1/8" line and is rated to handle 10KW of average power. Other units of this type are available in 1-5/8", 3-1/8" and 6-1/8" coaxial line.

Circle Reader Service Card 123

— *m w j* —

LITTON L-BAND KLYSTRONS

Broadband Klystrons at L-band have been announced as currently available by Litton Industries' Electron Tube Division. Designated L-3283, the tubes achieve gain and power characteristics which are essentially flat over the minimum bandwidth of 50 Mc. Minimum peak power output at band edges is 2 MW. The tubes' linear phase shift versus frequency characteristic makes them ideal for sophisticated radar systems requiring electronic tuning and pulse shaping. Other broadband Klystrons are under development by Litton.

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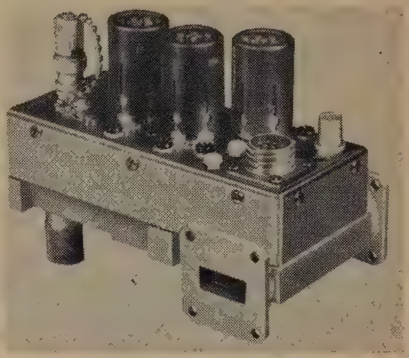
— *m w j* —

LEL MODEL MMX-3 MATCHED MIXER-PREAMPLIFIER ASSEMBLY



This newest addition to LEL's series of integrated mixer-preamplifiers provides a further coverage of X-band in a standard stock unit.

Operating over the 10.5 - 12.4 KMC spectrum, the MMX-3 is gain stabilized, has a

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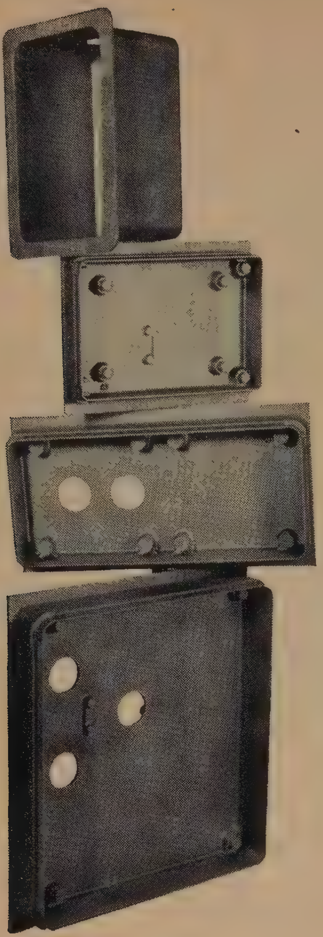

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20mc I. F. bandpass centered at 60mc, 25db minimum overall gain, and a 9db maximum noise figure. The MMX-3 provides a 50 ohm output impedance making it suitable for gain and noise figure measurements on masers and parametric up-converters in addition to its use as standard sub-assembly for incorporation into a radar or missile receiving system.

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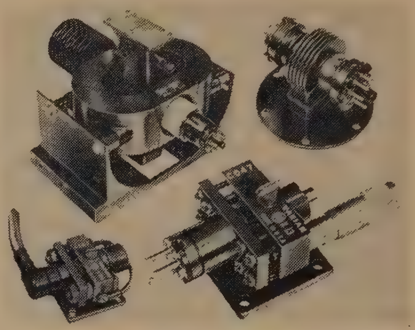
— *m w j* —

VARIAN ADOPTS MEYERCORD TYPE "C" DECALS FOR MARKING KLYSTRON TUBES



Varian Klystrons are made in various sizes from the dimensions of a flashlight battery to monsters 12 feet long. Marking Klystrons had presented a problem for Varian until Meyercord Type "C" Decals were adopted for this purpose.

These decals achieved the traditional effect of printing or silk screen marking, so common in the tube industry, while overcoming the usual short-comings of printing over curved areas or when applied to inaccessible surfaces.

The Type "C" Meyercord decals were particularly useful because they provided an open type letter in comparison with opaque backing employed in other decal types.

The decals were subjected to rigorous temperature and humidity tests before adoption. Manufacturer of the decals is The Meyercord Co., Chicago, Illinois.

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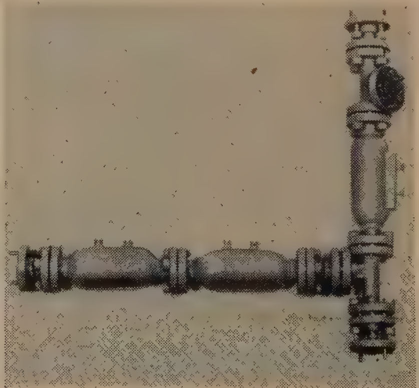
— *m w j* —

V-BAND MILLIMETER-WAVE FERRITE COMPONENTS INTRODUCED BY T. R. G., INC.



A new line of millimeter-wave ferrite components is now available from T. R. G., Inc., of Somerville, Mass. to the microwave engineer working in the V-Band, covering 60-75 KMC. The new components includ a compact Ferrite Isolator, a fast-operatin Ferrite On-Off Switch or Variable Attenuator, a Ferrite Circulator, and a Ferrite Hig Power Reciprocal Switch.

These are believed to be the first V-Ban components of this type to be availab commercially.

Lightweight and miniaturized, each component will withstand pressurization to 3 p. s. i.

Ferrite Isolator, Model V-FL 1, is a compact unit used to isolate generator fro load. It operates as a non-reciprocal 45 rotator with a permanent magnet supplyin the bias field. Isolation is larger than 17 d over at least a 3% band with insertion lo less than .6 db.

Ferrite On-Off Switch or Variable Attenuator, Model V-FSW 1, is a low-pow lightweight fast-operating switch with hig isolation when off, low loss when turne on. Switching is accomplished by a coil 1 to 2 microseconds.

Ferrite Circulator, Model V-FC 1, is lightweight four-port device using polariz tion rotation as the basic non-reciprocal el ment. A non-reciprocal 45° rotator combined with dual-mode transducers plus input and output taper sections make up t complete circulator. Peak power unpressurized is 10 KW, average power 2 wat

The Ferrite High-Power Reciproc Switch, Model V-FSW 2, is a reciproc lightweight ferrite rotator switch. means of a ferrite rotator and a dual-mo transducer an input signal may be switch to either of two arms. Switching time 1 to 2 microseconds. Peak power is least 10 KW, unpressurized.

All components are available from sto and are designed to meet military standar A catalogue complete with detailed speci cations is available.

Circle Reader Service Card 12

— *m w j* —

NEW WAVEFORM SYNTHESIZE

The new Type 200 Waveform Synthesi developed in the laboratory of Exact El tronics, Inc., Portland, Oregon, permits operator to create a stable output wavefo of almost any shape imaginable. Unlimi configuration is achieved by separately c trolling the characteristics of small segme of the total waveform, using different pl in units.

With the Type A Variable Slope Plu Unit, the Synthesizer provides an al limitless number of wave shapes. The plitude and slope of each of the 50 inc ts may be independently varied without raction to create the desired waveform; the over-all amplitude and waveform tion may then also be varied over a range.

hen used with the Type C Variable th Plug-in Unit, the Synthesizer pro- s 50 output pulses with independently able width as well as amplitude. Over- mplitude and waveform duration may also be varied as in the "A" Plug-in. uture plug-ins presently being developed extend the flexibility of the Type 200 eet the most complex demands.

iterature is available on request.

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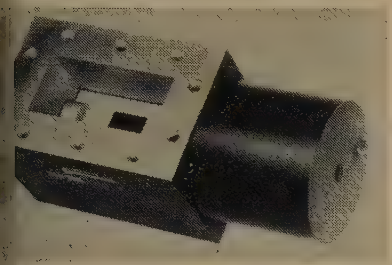
— *m w j* —

NEW S-BAND ROTARY WAVEGUIDE SHUTTER



he MA-788 rotary shutter from Micro- Associates, Inc., of Burlington, Mass., new, compact, magnetically operated eguide switch for use in RG-48/U S- l applications (2.7-3.1 kMc).

he operating voltage is 20-29V DC. ent at 28V is 560 milliamps and coil tance at 25°C is 50 ohms. In the norm- closed position the shutter provides lb attenuation for reliable standby pro- on of receiver elements.

the open position the MA-788 inser- loss is 0.2 db maximum and VSWR n position) is 1.0 maximum. The shut- is designed to operate under military litions of shock, vibration (5G at 50 to cps) and temperature cycle from —40 100°C.

he MA-788 is one of the six magnetically ated shutters available. The others cover Ku-, and Ka-bands. The shutters are lied either separately or as components mplete duplexers. Additional informa- is available from the manufacturer.

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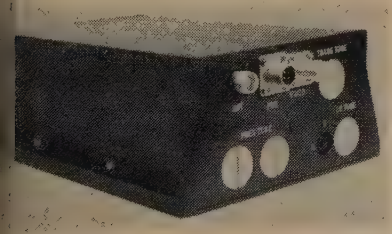
— *m w j* —

C-BAND TRANSPONDER FROM AERO GEO ASTRO



gnificant advance in the design of C- l transponders for air and space applica- s has been announced by Aero Geo o Corp. of Alexandria, Virginia. The s permit secure long range tracking patible with present day instrumentation rs.

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AN/APW-11A transmitter cavity for 2C40. Complete S band coverage at max. power. Temperature compensated. New $77.50 ea.

AN/APS-10 3CM. X BAND RADAR
Complete RF head including transmitter, receiver, modulator. Uses 2J42 magnetron. Fully described in MIT Rad. Lab. Series Vol. I, pps. 616-625 and Vol. II, pps. 171-185. $375.00. Complete X band radar system also avail. incl. 360 deg. antenna, PPI, sync, pwr supply. Similar to $17,000 weather radar now in use by airlines $750 complete.

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US Navy Raytheon 275 KW peak output S band. Rotating yoke Plan position Indicator. Magnetron supplied for any S band frequency specified, incl. Weather Band. 4, 20 and 80 mile range. 360 degree azimuth scan. Sensitive rcvr using 2K28/707B and 1N21B. Supplied brand new complete with instruction books and installation drawings. Can be supplied to operate from 32VDC or 115 volts. Price $975. Ideal for weather work. Has picked up clouds at 50 miles. Weight 488 lbs.

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Rotates thru 360 deg. either hand or motor driveable. New, $22.50 ea.

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10 CM. RADAR BEACON FOR GUIDED MISSILES. 14" pressurized housing. 2C40 lighthouse OSC. Trans-rcvr. unit $275.00.

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FLEXIBLE WAVEGUIDE. 1x.5 X band 4", new $5.00. 1x.5 X band 9" Technicraft. New $10.00. 1.5 X band 24" Airtron. New $21.50. 1¼" x ⅝" X band 12" Western Elec. New $19.50.

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SMX-32 Amplifier-Multiplier 9.0-10.5-KMC. Amp. freq. multiplier; output power 1.5 to 2 watts at 9000 to 10,500 mc; drive freq. 4500 to 5250 mc. New in original sealed cartons. Guaranteed 90 days. Regular price $925 ea. Our price $425 ea.

SMC-11A Frequency multiplier. Output range 4640-4670 mc. ½ to 1 watt on 6th harmonic. Input range 773-778 mc. For direct control of microwave frequencies. New in original sealed cartons. Guaranteed 90 days. Regular price $1500 ea. Our price $495 ea.

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Includes Rectifier xfmr 5800/7000V, 2.2./2.55-KVA; Resonant charging choke 150 cy. 30H 12 Amp. Ins. 17KV; Capacitor network 17E2-2-300-25P2T; Capacitor .04Mfd. 17KVDC; Transformer 4400V to 22,000V; Fil. Xfmr. & Filter choke 5.1V 18Amp, 6 H .21Amp. DC; 4C35 pulser, 3B24W (6 each), WL1B41 gap tube. Price new type MD-53/APS20C $1125.00

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350 to 1400mc countermeasures jammer. 115V 60 cy AC input. New and complete operating unit. $750.00

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TAPER. RG51 to RG52 (1¼ x ⅝" to 1 x ½") Smooth Electroform. Standard Flankes. New $16.50.

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Full azimuth and elevation sweeps. 360 degrees in azimuth. 210 degrees in elevation. Accurate to 1 mil. over system. Complete for full tracking response. Includes pedestal drives, selsyns, potentiometers, drive motors, control amplidynes. Excellent used condition. This is the first time these pedestals have been available for purchase. Limited quantity in stock for immediate shipment. Ideal for antenna pattern ranges, radar systems, radio astronomy, any project requiring accurate response in elevation and azimuth. Compl. operations console all housed in trailer.
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VG-12" PROJECTION PPI RRTR $395.00.
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15,250 to 16,250mcs, calibrated attenuator. 115VAC regulated power supply. Mfg. Polarad. Exc. condition $1250. each

KLYSTRON MOUNTS
3CM. Precision Tube Mount. Waveline model 688. X band shielded klystron mount PRD signal generator type. Complete with variable glass vane attenuator. Brand new. $205. list. Price $45.00.
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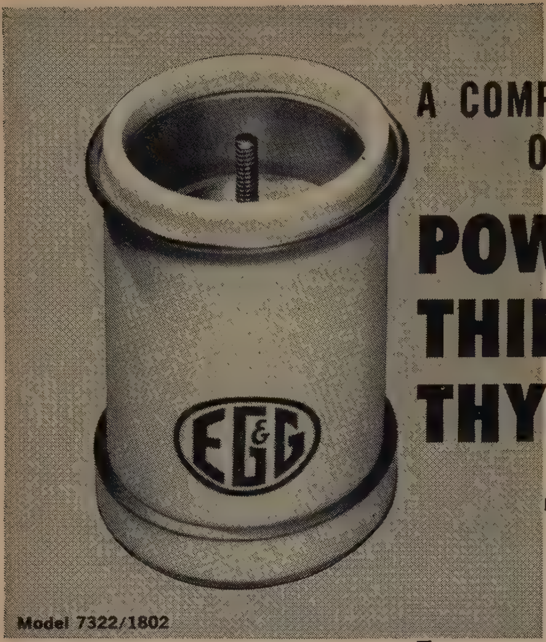

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• light weight (lbs.)	2.07	0.82	0.13
• max. peak anode voltage	25,000	20,000	8,000
• max. peak anode current (amps)	1,500	500	90
• max. average current (amps)	1.5	0.5	0.1
• wide temperature capability	—55°C to +125°C ambient; 400°C envelope max.		
• long life	unique hydrogen reservoir in all models.		
• rugged dependability	all models pass vigorous shock and vibration tests.		
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on applications exceeding the above ratings, write or call:

Applications Engineering Department...
EDGERTON, GERMESHAUSEN & GRIER, INC.
160 Brookline Ave., Boston 15, Mass., (Tel: COpley 7-9700)

Other Offices: 1622 South "A" St., Las Vegas, Nev. • Bldg. 226, Santa Barbara Airport, Goleta, Calif.

The figure of merit (based on weigh volume and power dissipation and expressed as the PWC radio — Pound Watts per cubic Inch) for this C-band transponder has been announced as 1.67 i comparison PWC ratios of 5 to 6 for earlie equipments.

The electrical characteristics of this transistorized model represent superheterodyn sensitivity, single or three pulse interrogation and a 400-watt transmitter outpu Internal duplexing for single antenna operation in the d.c.-to-d.c. converter is inco porated. The overall dissipation of the un at a nominal repetition rate is under 3 watts. The volume occupied by the transponder is only 128 cubic inches with weight of 7 pounds 2 ounces.

Further information is available from th manufacturer.

Circle Reader Service Card 13

— *mwj* —

HERMES ELECTRONICS AWARDE PATENTS FOR CRYSTAL FILTER

Hermes Electronics Company has bee awarded three patents for crystal fi ters and related devices vital to missile rada guidance systems and Intercontinental Ba listic Missile warning systems, Malcolm M Hubbard, President, announced recently.

The patents, which were granted to D David I. Kosowsky, Manager of the Filte Division, and assigned to the compa cover a crystal discriminator network, hybri type filter networks and a frequency modulating system for crystal oscillators. R. W Luscher is co-inventor of the frequen modulating system for crystal oscillator The newly patented networks were invente as part of Hermes' continuing research program, Mr. Hubbard said.

Licensing arrangements have already bee concluded with the Danish firm, A. S. Br vour, Division A. G. A. Industries. Othe negotiations are being conducted with bot foreign and domestic manufacturers.

A characteristic of Hermes crystal filter discriminators and oscillators is their uniqu selectivity which permits a higher volum of radio and radar transmissions witho overlapping or interference of signal Other characteristics important to their u in missiles are their small size and the ability to operate under extreme enviro mental conditions.

Circle Reader Service Card 13

— *mwj* —

MICROWAVE FERRITE SINGLE SIDEBAND MODULATOR

RANTEC Corporation Model MX 2 Ferrite Single Sideband Modulator pr duces frequency translations of the i coming signal by means of two ferri balanced modulators whose outputs a combined in the proper phase relatio ships. These units produce frequen offsets up to 150 kc with conversi losses of less than 20 db.

(*Continued on page 108*)

Circle Reader Service Card 61

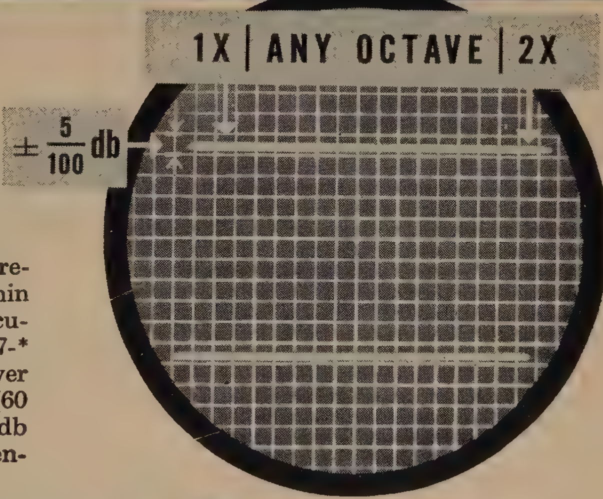
JERROLD

PRECISION SWEEP FREQUENCY GENERATOR model 707-*

5/100 db

ULTRA FLAT

Featuring...variable-rate, all-electronic sweep with plug-in oscillators covering 2 to 265 mcs.



The ultra flat sweep generator model 707-* is a precision instrument with an rf output that is flat within ±5/100 of a db over highest single octave. Particularly adaptable for use with an X-Y plotter, the 707-* features: plug-in oscillator heads; high output power (+20 dbm below 150 mcs.); variable sweep rate (60 per sec. to 1 per 2 min.); and harmonics down 40 db over highest single octave (down 30 db over the entire range).

*Order Model 707-1, 2, or 3 shipped respectively with oscillator heads H-71 (4-100 mcs.), H-72 (12-220 mcs.), H-73 (2-50 mcs.) **$795.00 each**

Model 707-4 shipped with H-74 (any single octave 2-265 mcs.) special order..**$845.00 each**

Additional oscillator heads for any model 707

H-71, H-72, and H-73..............................**$250.00 each**

H-74 special order.................................**$275.00 each**

HIGH
output power—
+20 dbm

WIDE
sweep width—1% to
over 120% of c.f.

FLAT
output—±.05 db over
the highest octave

Write for catalog and technical Newsletter series on Measurements By Comparison using sweep frequency techniques. Prices and data subject to change without notice.

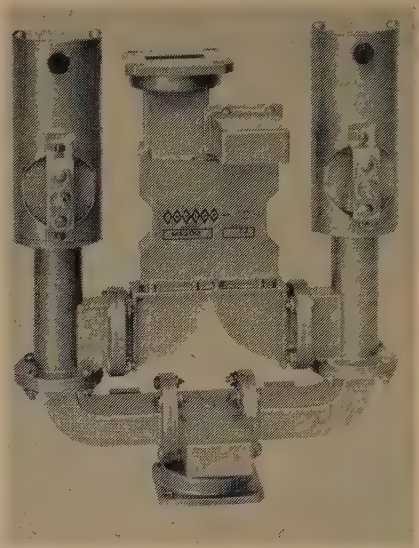
RROLD **ELECTRONICS CORPORATION, Industrial Products Division**
Dept. ITE-11 The Jerrold Building, Philadelphia 32, Pa.
Jerrold Electronics (Canada) Limited, Toronto
Export Representative: Rocke International, New York 16, N. Y.

VISIT US AT THE IRE SHOW • BOOTH 3056

Circle Reader Service Card 62

New Products

(*Continued from page 106*)



Operation in the frequency band 9.6-10.6 kmc is possible with slight adjustments for carrier suppression. Undesired sidebands are suppressed below 20 db over a 2% band without adjustment.

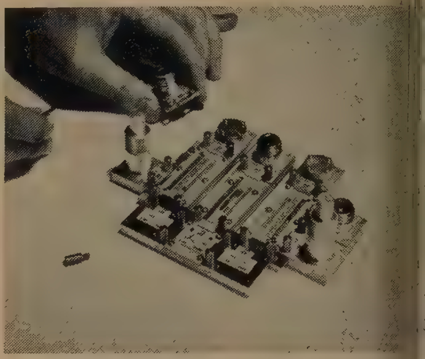
At single frequencies suppression of 50-60 db for unwanted sidebands is possible. These devices are useful for simulation of doppler frequency shifts, generation of local oscillator signals, and in radar ranging applications.

RANTEC also produces a series of two-phase drivers for use with these devices. Single sideband modulators are also available in other frequency bands.

Circle Reader Service Card 13

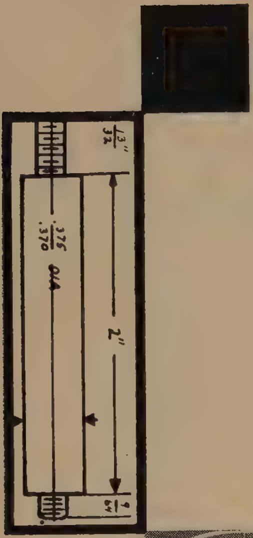
— *mwj* —

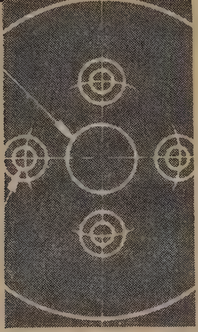
SANDERS ADDS L-BAND COMPONENTS TO TRI-PLATE LINE



Addition of a new group of L-Band components (1-2 kmc) to its line TRI-PLATE® strip transmission line modules is announced by Sanders Associates, Inc. Components in the new frequency range are especially useful in design work for microwave computers, well as radar, communications, radio astronomy and countermeasures.

Addition of the new L-Band units round out the group of TRI-PLATE components in this frequency range.





Product Development of

POLYIRON PERMEABLE DIELECTRIC

Attenuation UP TO 300 D.B. per inch

No other commercial dielectric can match POLYIRON'S numerous advantages:

- Easily molded or machined to any shape.
- Lower standing wave ratios therefore greater energy transfer.
- Relatively short terminations.
- Impedance data remarkably independent of wave lengths.

CUSTOM COMPONENTS Applications:

RF Gaskets, Waveguide Switches, Extending range of vane attenuators, Multi Conductor Filter Blocks, Terminations and Pads, Dummy Loads.

Deliveries co-ordinated with your needs. Special Shapes and Materials to fill your Specifications.

For details write or call:

CUSTOM
P.O. Box 248 Caldwell, N.J. • CApital 6-3404
COMPONENTS
inc.

Circle Reader Service Card 63

PERMANENT MAGNET FOCUSED ★ TRAVELING WAVE TUBE AMPLIFIER ★

Model TA-20PM

The Model TA-20PM permanent magnet focused traveling wave tube amplifier is a lightweight, compact instrument applicable to many uses in the operating frequency range 8.2 to 11.0 KMC. The ruggedized power supply provides 0.1% regulation, with maximum ripple on the helix less than 10 millivolts. Front panel metering provided for helix voltage, helix current, and beam current. The unit has been designed for relay rack or cabinet mounting.

Please write to Department A for complete specifications

MPE
MENLO PARK ENGINEERING
711 Hamilton Avenue Menlo Park, Calif. DAvenport 6-9080

Circle Reader Service Card 64

ude hybrid rings, 3 db and 20 db plers and a 25 ohm to 50 ohm trans- ner. These components will mate the broadband transitions, power ders, right angle vertical and hori- al bends, 180° bends, straight sec- s, crystal mounts and terminations used in association with the existing lers' TRI-PLATE® modules at both er and lower frequencies.

hese TRI-PLATE® modules are dardized "building blocks" for de- ers working on microwave strip trans- ion circuits. All of the components be quickly connected by thumbscrews nake up a circuit conforming closely pace factor and weight to an inte- ed strip transmission line circuit.

hey may be used for breadboarding nits with substantial savings in time material, and are suited for short production of microwave equipment.

cle Reader Service Card 133

— *mwj* —

EATHERPROOF ASTRODOMES

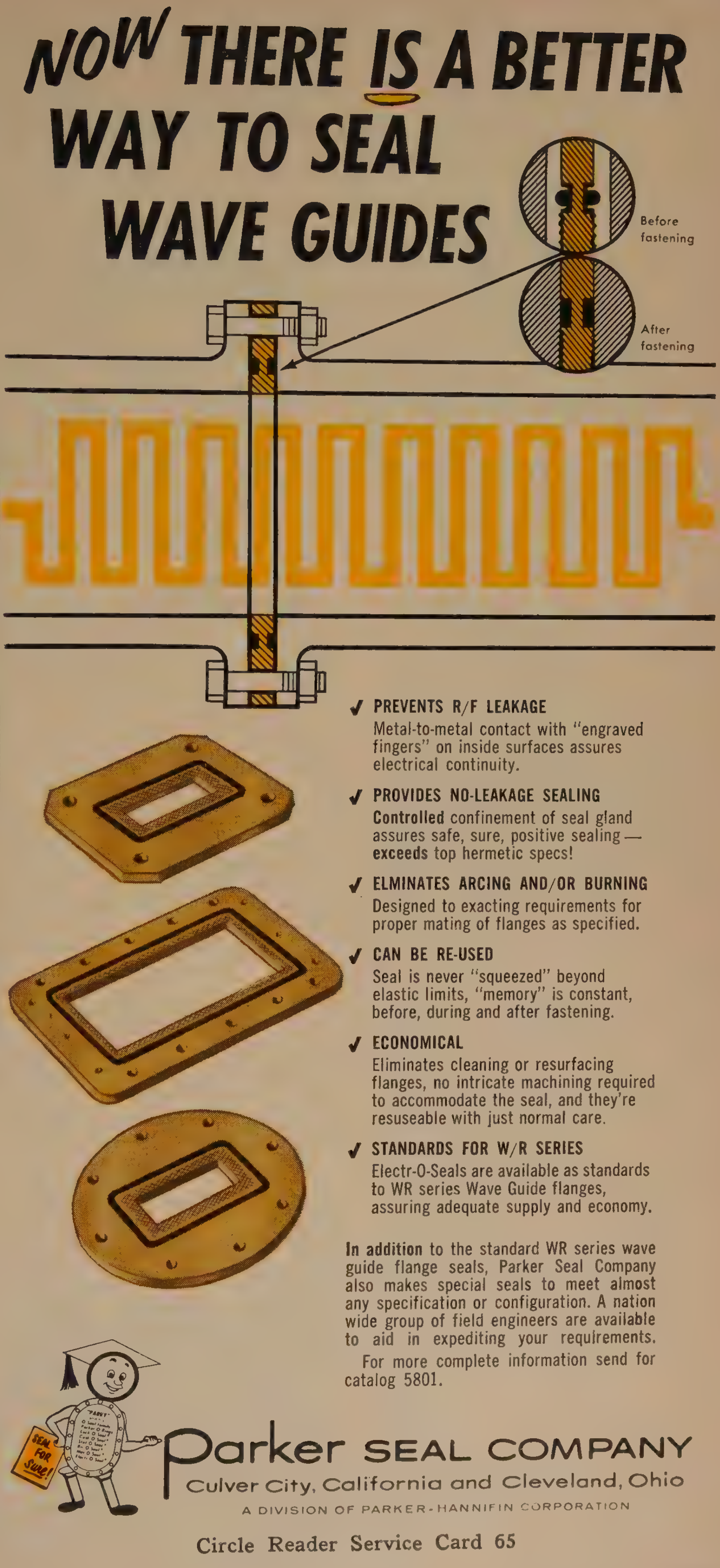
strumentation and motion picture ras, telescopes and other equipment in tracking missiles are protected the elements by large astrodomes ufactured by the Houston Fearless . Of insulated sandwich construc- they are made of impregnated eycomb covered with fiber glass, eving an exceptionally high strength- ht ratio without the use of a sup- ing structure. When closed they are ght and weatherproof, offering posi- protection against the elements. They provide effective insulation from heat.

e metal base is inner-lined with egnated honeycomb insulation cov- with fiber glass. The viewing aper- is power driven and can be opened losed quickly. The entire dome ro- on the base cylinder, powered by yotron or hydraulic servomechanism automatic tracking.

r conditioning is provided when de- . Virtually any diameter of dome be fabricated.

cle Reader Service Card 134

— *mwj* —



NOW THERE IS A BETTER WAY TO SEAL WAVE GUIDES

✓ **PREVENTS R/F LEAKAGE**
Metal-to-metal contact with "engraved fingers" on inside surfaces assures electrical continuity.

✓ **PROVIDES NO-LEAKAGE SEALING**
Controlled confinement of seal gland assures safe, sure, positive sealing — **exceeds** top hermetic specs!

✓ **ELMINATES ARCING AND/OR BURNING**
Designed to exacting requirements for proper mating of flanges as specified.

✓ **CAN BE RE-USED**
Seal is never "squeezed" beyond elastic limits, "memory" is constant, before, during and after fastening.

✓ **ECONOMICAL**
Eliminates cleaning or resurfacing flanges, no intricate machining required to accommodate the seal, and they're resuseable with just normal care.

✓ **STANDARDS FOR W/R SERIES**
Electr-O-Seals are available as standards to WR series Wave Guide flanges, assuring adequate supply and economy.

In addition to the standard WR series wave guide flange seals, Parker Seal Company also makes special seals to meet almost any specification or configuration. A nation wide group of field engineers are available to aid in expediting your requirements.

For more complete information send for catalog 5801.

Parker SEAL COMPANY
Culver City, California and Cleveland, Ohio
A DIVISION OF PARKER-HANNIFIN CORPORATION

Circle Reader Service Card 65

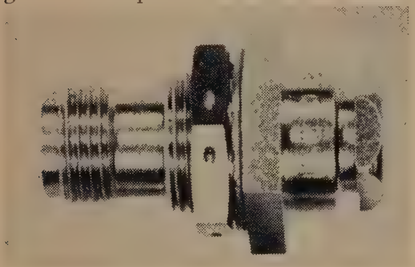
BOOTH INFORMATION

KINGS ELECTRONICS CO.

Booths 2821 - 2823

Coaxial connectors plotted to enable users to select units which meet the desired VSWR in critical applications can now be furnished by Kings Electronics Co., Inc. of Tuckahoe, N. Y. in the 5,000 - 11,000 megacycle range. These connectors have an absolute reliability of VSWR of 1.25:1 or better and are designed especially for missile and precision equipment.

Their extremely dependable performance is assured since each connector is individually tested and calibrated within the Kings' laboratories. A calibration curve is supplied with each connector which can be tested and plotted at every 100 mc point over the entire range if so desired. Both KA 11-06 and KA 51-05 coaxial connectors are part of the Kings' TNC group and are available for specific or broad band use. They are manufactured to meet government specifications.



These will be part of Booth No. 2821 - 2823 at the I.R.E. Show which will display the complete line of KINGS coaxial connectors and other products.

— mwj —

HEWLETT - PACKARD

Booths 3302 - 04 - 06 - 3401 - 03 - 05

Fifteen new instruments and systems for making time-saving electronic measurements will be displayed by Hewlett-Packard Company at the 1960 IRE Show in New York City, March 21-24.

Hewlett-Packard's new equipment, augmented by several instruments recently introduced by the company, will be arranged in actual test setups to demonstrate the speed, convenience and accuracy of modern instrumentation.

The company's exhibit will be located between the escalators and elevators on the third floor of the New York Coliseum. Booth numbers are 3302, 3304, 3306, 3401, 3403 and 3405.

One of the new instruments to be shown is the Model 411A 1 KMC Voltmeter. An extremely versatile instrument, this new VTVM has a frequency range of 5 KC to 1 KMC. Voltage range is 1 millivolt to 10 volts, with 10 millivolts full scale sensitivity. Accuracy is ±3% of full scale, 10 KC to 50 MC; ± 6% of full scale, 50 MC to 150 KMC; ± 1 db, 5 KC to 1 KMC. The voltmeter has a large linear meter scale.

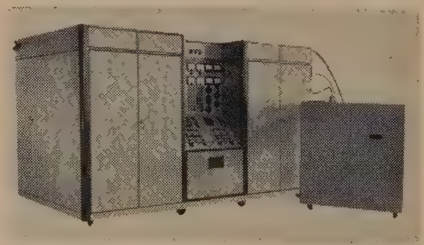
Other new instruments on display include: Model 166C Display Scanner; Model 468A DC Amplifier; Model 185A Oscilloscope; Model 113AR Frequency Divider and Clock; Model 103AR Stable Crystal Oscillator; Model 724 AR Stand-by Power Supply; Model 120AR Oscilloscope; WR75 Waveguide Components; Model 938A/940A Frequency Doubler Sets; Model 344A Noise Figure Meter; Model 456A AC Current Probe.

— mwj —

MANSON LABORATORIES, INC.

Booth 3213

The Manson Model 330 Hard-Tube, High Voltage Pulse Modulator offers unusual flexibility for operating a wide range of magnetrons. One of several recent high power modulators built by Manson Laboratories, this equipment typifies units which will be pictorially on view at the Company's booth at the IRE Show.



The Model 330 provides a continuously adjustable pulse width range of 1 to 15 microseconds at repetition rates of 100 to 1000 pps. Pulse energy to the primary of the pulse transformer, which is housed in a separate cabinet, is 20 KV peak at 600 amps. Designed for a .002 duty cycle, t equipment delivers a maximum avera power of 24 kilowatts.

The equipment includes monitoring c cuits for observing both output pu voltage and current, as well as meters f all pertinent AC & DC voltages and c rents. A low-capacity filament supply f the tube under test is also incorporated.

The equipment is fully self-contain requiring only 208 V, 3 phase line pow for operation. The unit is completely se checking to assure safety to both equ ment and personnel.

— mwj —

BURNELL & CO.

The new MT series of microminiatu Kernel toroidal inductors which provi lightest weight, maximum reliability a considerable economy in printed circ use will be shown by Burnell & Co., I at Booth during the IRE Show.

First of the series, the MT 34 mic miniature Kernels are recommended frequencies to 30 kcs and can be suppl with inductances up to 500 mhys. W inductances up to 200 mhys, MT 35 Ke els are applicable to frequencies rang to 200 kcs.

Q for the MT 34 is greater than 55 25 kcs and for the MT 35 more than at 100 kcs. Size of the MT 34 and MT Kernels is .417″ OD x .215″, spacing tween leads, .3″ x 1″ long with a wei of .06 ounces.

Completely encapsulated, the new 34 and MT 35 Kernels will withstand usually high acceleration, shock and bration environments.

— mwj —

HUGGINS LABORATORIES

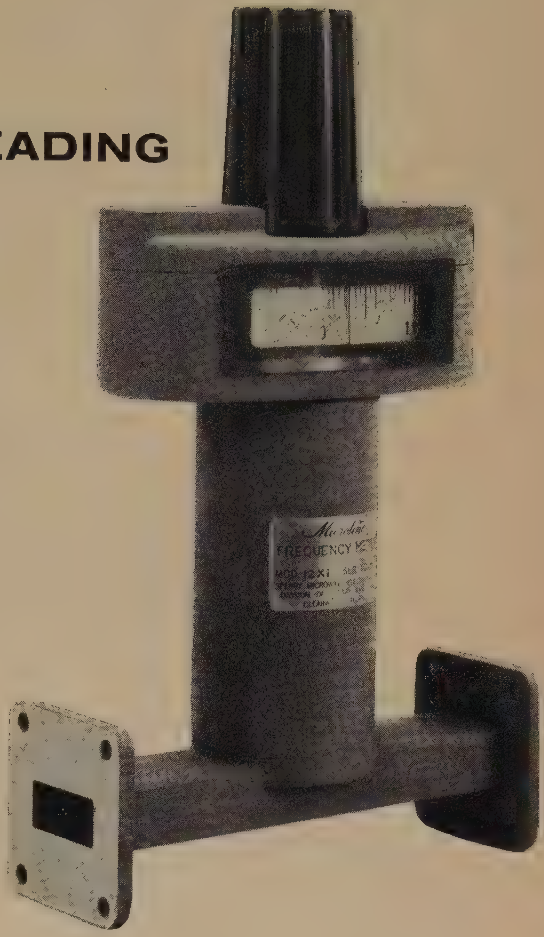
Booths 2917 - 18

An electrostatic focused 1 watt Tra ing Wave Tube, the HA 58 has been

(*Continued on page 112*)

NEW FOR FAST, ACCURATE, CONVENIENT FREQUENCY MEASUREMENTS

SPERRY *Microline*® DIRECT READING FREQUENCY METERS



Sperry has now developed a new family of Direct Reading Frequency Meters. These new instruments, covering the S, C, X, U, and K bands, provide the ultimate in convenient frequency measurements while still maintaining the accuracy necessary for most applications.

These frequency meters use a revolutionary steel tape drive for fast, accurate reading; misinterpretation is eliminated since only a small segment of the readout tape appears under the window at any given setting.

Model No.	Frequency Range (Kmc)	Absolute Accuracy	Reaction Type Q	Scale Length (in.)	Smallest Scale Division (Mc)	Price
12S1	2.60-3.95	.08%	12,000	82	1	$450
12C1	3.95-5.85	.08%	10,000	82	2	$250
12X1	8.2-12.4	.08%	8000	80	5	$150
12U1	12.4-18.0	.1 %	7000	81	10	$210
12K1	18.0-26.5	.1 %	6000	113	5	$220

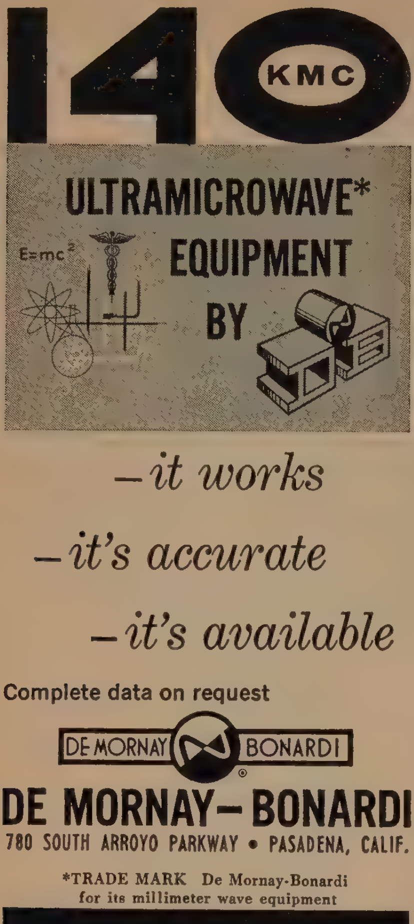
AT THE NEW YORK IRE SHOW

See these new direct reading instruments, along with Sperry's complete line of high precision micrometer frequency meters. We'll be looking for you at Booths 2432 to 2438.

SPERRY

SPERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATION*

Circle Reader Service Card 66


140 KMC

ULTRAMICROWAVE* EQUIPMENT BY

–it works

–it's accurate

–it's available

Complete data on request

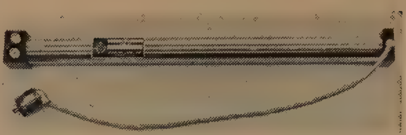
DE MORNAY ® BONARDI

DE MORNAY–BONARDI
780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

*TRADE MARK De Mornay-Bonardi for its millimeter wave equipment

Circle Reader Service Card 67

(*Continued from page 110*)



veloped by Huggins Laboratories of Sunnyvale, California.

This addition to the Huggins line of TWT's operates on a frequency range of 500 to 1000 MCS, with a small signal gain of 30 DB minimum, and a saturation gain of 28 DB minimum. Substantial savings in weight and size have been effected in the HA 58 which measures 1-¼″ diameter and 18″ in length. The tube is unusually rugged. No magnetic structure either solenoid or permanent magnet is needed by the HA 58. Operating temperature range, vibration, and shock performance meet the requirements of military specifications.

— *m w j* —

ROHDE AND SCHWARTZ SALES COMPANY
Booth 3000

Rohde and Schwartz Sales Company, (U.S.A.), Passaic, New Jersey, will exhibit the following new items at the IRE show: The type CAA Primary Time Standard; type USVH 10kc-30 mc Selective Microvoltmeter; type SLRD 275-2750 mc UHF Power Signal Generator; type XZA Primary Frequency Standard; type SWOB Polyskop, as well as FM relay receivers and communications receivers.

BROADBAND "Pressurized" SECTOR SCAN ROTARY JOINTS for HIGH POWER OPERATION

LIECO is in full production on its newest designs of Step Twist Rotary Joints for scanning ±90° sectors.

- VSWR: 1:15 max.
- Frequency: Full waveguide band.
- Power: Full waveguide power
- Low Insertion loss.
- Material: Brass or aluminum
- Input and Output: on same axis

LIECO is also in production of a ±360° Sector Scan Rotary Joint for RG-96/U Wave Guide. The 360° Joint is currently being developed for additional waveguide sizes to eventually complete this series.

These joints are also available to any degree of sector scan on special order.

IRE Booth 2435

LIECO INC.

EILEEN WAY • SYOSSET, L.I., N.Y.
Phone WAlnut 1-6300

Circle Reader Service Card 68

The Rohde and Schwartz booth will manned by Messrs. R. Feldt, Preside J. L. Fisher, and E. E. Bick.

— *m w j* —

W. L. GORE & ASSOCIATES
Booth 4121

Several new constructions in single-co ductor wire and multiple-conductor ribbon cables will be shown for the fi time at the IRE Show by W. L. Gore Associates, Inc., Newark, Del.

The new hookup wires embody no approaches in the formulation of w coatings to solve the problems of ab sion, cut-through and corona-stress fail long associated with PTFE (Teflon) sulations.

The firm will also demonstrate effectiveness of its new Tetra-Etch, means of quickly and inexpensively ma ing Teflon bondable to itself and to ot materials.

The Gore exhibit will be in Booth N 4121.

— *m w j* —

P. R. MALLORY & CO.

Among the new products to be hibited by P. R. Mallory & Co. Inc. the IRE Show are examples of solid st circuitry developed by the Mallory El tronics Division. One of these is a ti delay relay which has been used in U. satellites; adjustable from .2 to 10 utes, the relay was developed in Mallor West Coast Laboratory at Lynwood, C fornia. Others include a solid state ti ing device developed for the "Hou Dog" missile and a transistorized pow supply for electroluminescent lighting.

A mercury battery for low temperat use and a new voltage reference batt will be among the battery systems in Mallory exhibit.

Three new types of capacitors will shown. These include a new miniat tubular capacitor designed for extre reliability and long life and a new lo cost tubular capacitor for commercial plications. The complete Mallory line tantalum capacitors will be featured.

Mallory will introduce its new ½-in diameter carbon control in this exhib it is the smallest conventional-type c trol designed for commercial applicatio

The Mallory Distributor Division w feature its industrial program, which ables users of electronic components get immediate delivery from local sto at factory prices.

— *m w j* —

D. S. KENNEDY COMPANY
Booths 2532 and 2637

D. S. Kennedy and Company, Cohas Massachusetts, Antenna manufactu will feature a new spincasting process which, according to the company, surface accuracy of a paraboloidal ante is increased by more than ten times. K nedy will be at Booths 2532 and 263

Booth personnel will include R. Grenzeback, J. C. Cotney, F. R. H R. H. Hawes, J. J. Flynn, and J. Kennedy.

MENLO PARK ENGINEERING
Booth 3836

new microwave power leveler, the es 500, has been developed by Menlo k Engineering of Menlo Park, Cali- ia and will be introduced for the time at the 1960 IRE show. The unit sed to control output variations from aveling wave amplifier or backward e oscillator. This is accomplished by edback process, whereby a sample of output power is used to generate an r that is impressed on the amplitude ulation element of the TWA or O.

recise power leveling can be performed the series 500 instruments regardless he fact that the output power from controlled device may be a rapidly ing function with respect to time or be swept in frequency to rates ex- ing 100 cycles per second. Voltage of the 500 series is 80 DB maximum controlled internal feedback for sta- y. Gain is adjustable over five over- ing ranges from 47.0 to 80.0 DB. ier control allows flexibility of ad- ment. Ranges are 50, 60, 65, 70 and DB. DC Amplifier Bandwidth is within ± 0.5 DB from DC to 20 Kc. B at 100 KC/s.

— *mwj* —

F. J. STOKES CORP.
Booths 4125 - 4126

wo recent additions to its wide range roduction equipment for the electron- ndustry will be prominently featured e exhibit of F. J. Stokes Corporation, adelphia, at the 1960 Radio Engineer- Show. The Stokes display will occupy es 4125 and 4126, on the fourth floor.

he first of these new products is the ntly redesigned Model F-4 compact- press, which will be shown in opera- . This versatile press is a 4-ton single- ch unit which is ideal for making netic seals, tantalum capacitor anodes, um titanate shapes, ferrite cores, glass ls, TV-gun mounts, and other elec- ic components.

lso on display will be an improved ion of this company's vacuum "bak- oven" for outgassing and sealing semi- luctor components under high vacuum n outstanding example of Stokes' capa- ies for designing special vacuum pro- ing equipment. The manufacture of e components calls for the fabrication assembly of thin slices of crystallized on, germanium, and other highly re- ve materials. Outgassing these ma- ls calls for a very high vacuum; cer- other operations — such as fusing or ing the component into the sub-as- bly — require moderate amounts of

WL

In the field of microwave engineering, Wheeler Laboratories occupies a unique position as an industrial laboratory devoted exclusively to consulting and development.

Main Office and
Microwave Laboratory
Great Neck, N.Y.

ON LONG ISLAND
WHEELER LABORATORIES, INC.
A SUBSIDIARY OF HAZELTINE CORPORATION

Antenna Laboratory
and Test Range
Smithtown, N.Y.

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

Harold A. Wheeler
and
Engineering
Staff

WL

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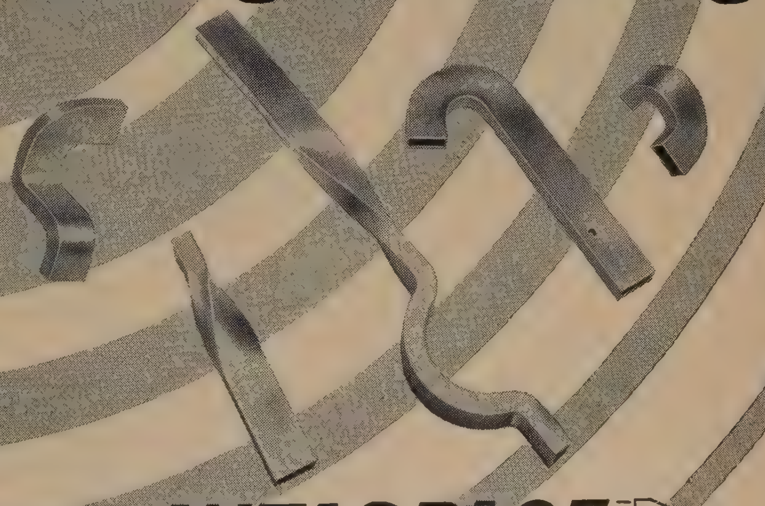
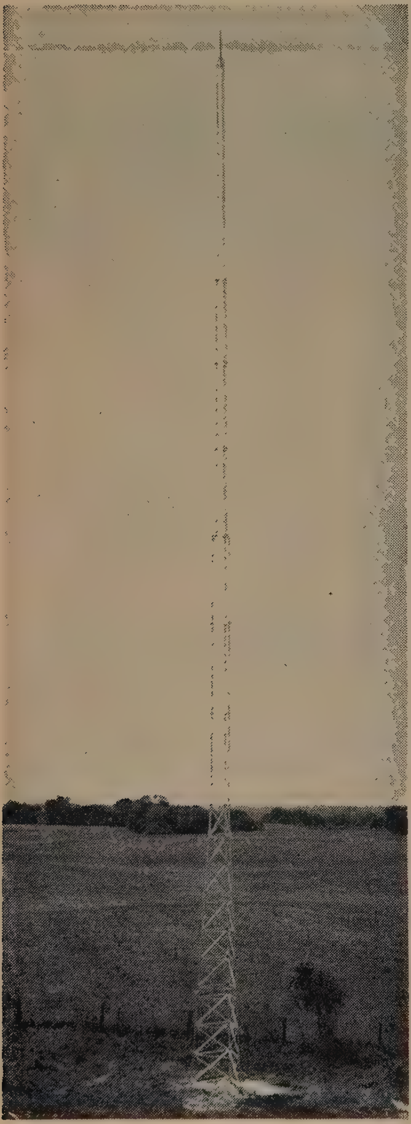
Waveguide
specialists in close tolerance
Bending and Forming



INTASPACE
CORP.
135-A ORANGE ST., BLOOMFIELD, N. J.
PILGRIM 8-4700

Circle Reader Service Card 70

New ROHN
SELF SUPPORTING
COMMUNICATION
TOWER

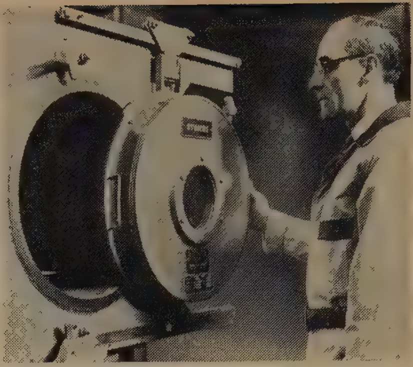


- 130 ft. in height, fully self-supporting!
- Rated a true HEAVY-DUTY steel tower, suitable for communication purposes, such as radio, telephone, broadcasting, etc.
- Complete hot-dipped galvanizing after fabrication.
- Low in cost—does your job with BIG savings—yet has excellent construction and unexcelled design! Easily shipped and quickly installed.

FREE *details gladly sent on request. Representatives coast-to-coast.*

ROHN *Manufacturing Co.*
116 Limestone, Bellevue,
Peoria, Illinois

"Pioneer Manufacturers of Towers of All Kinds"



heat and must therefore be carried out in a non-oxidizing environment. The special Stokes "baking oven" is a self-contained "package" unit which produces this environment and provides an efficient method of carrying out these operations.

Other new Stokes products being displayed publicly for the first time at this show will be its new ionization and cold-cathode vacuum gages — examples of the complete range of instrumentation for vacuum systems offered by this company.

— *mwj* —

BENDIX - RED BANK
Booths 2222 - 2231

The Red Bank Division, Bendix Aviation Corporation, Eatontown, New Jersey, will introduce three new reflex klystrons at the IRE show. These are ruggedized, low voltage, mechanically tuned Ka-band reflex oscillators designed for use as CW power sources over a frequency range of 34.0 to 35.6 kmc/s.

The new reflex klystrons are Bendix types TE-37, TE-53, TE-78, and are identical in electrical characteristics differing only in physical configuration as to mounting and coupling arrangements. They may be seen at Booth 2228.

— *mwj* —

PITOMETER LOG CORP.
Booth 3024

The Pitometer Log Corp. of New York will feature several new products at Booth 3024 during the IRE show. Included in the display will be Stable Local Oscillators (STALOS), High Temperature transistorized control amplifiers, and the series 800 Stalo stability tester.

Director of Research and Development, Bernard Kahn, will be on hand at the booth along with D. J. Kfeines, Norm Sturm, R. C. Rosaler, Rudy Volhard, Ed Bleistein, Gordon Silverman, Ed Wrobel, Michael Smolin and Bill Hallock.

— *mwj* —

MARCONI INSTRUMENTS
Booths 3301 - 3 - 5

Marconi Instruments Division, Englewood, New Jersey, a member of The Marconi Group of Companies, will show the following instruments for the first time at the IRE Show — Model 978 VHF Admittance Bridge, with 2% accuracy in the range 30-300 MC; Model 1064/2 mobile radio FM Generator; the new Model 3352 Pulse Generator; and the new Marconi Model 1342 low capacity Bridge

offering three-terminal capacity measurements from 0.002 $\mu\mu$F to 1000 $\mu\mu$ F wit accuracy of ± 0.2%.

— *mwj* —

AIR-MARINE MOTORS
Booth 2601

Air-Marine Motors will dramatically demonstrate their new vane axial blower that far exeeds environmental tests se forth in MIL-E-5422D at the 1960 I.R.E Show.

Designated as Model E2543-200, this blower has application wherever maximum air and medium static pressure are paramount. Utilizing a 2 5/16″ diameter motor, the blower, at 10,500 RPM will deliver 200 CFM at ¾″ Wg. It operates on a 200V, 3ϕ, 400 cycle source.

Due to unique design principles and Class F insulation, the vane axial blower withstands an ambient of 85° and has life in excess of 5,000 hours. It also meets MIL-E-5400B. Weighing only 3½ lbs. the housing dimensions are 4″ diameter by 4½″ long. Although not shown in photo, the unit is available with foo mounting.

Air-Marine Motors, of Amityville, N.Y. and Los Angeles, are noted for their design and manufacture of precision sub-fractional H. P. motors, blowers and fans

— *mwj* —

RADAR MEASUREMENTS CORP.
Booth 3005

Radar Measurements Corporation Hicksville, Long Island, will exhibit th firm's line of microwave equipment their IRE show Booth 3005.

Among the products shown will be th model 1200 Densiometer, model 130 Wattmeter, electronic switches, direction couplers, precision instruments, coaxi equipment and other microwave devices.

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ANDREW CORPORATION

Booths 1502 - 04

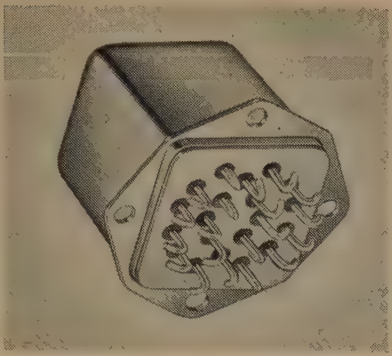
UBLOC antennas — large size para-
c antennas employing a new structural
ign resulting in new levels of per-
nance. Features high surface accuracy,
h rigidity to weight factor, easy in-
lation and light weight for given wind-
l rating. Construction of back frame
omplished with two basic elements;
ular bars and connecting hubs fabri-
d for press fit connection eliminating

ding or special tools for assembly.
hanical characteristics superior to con-
tional designs and methods presently
loyed in large antennas. Range of
s, up to 60 feet in diameter.

— *mwj* —

GUARDIAN ELECTRIC MFG. CO.

Booths 2502 - 2504



On display at Guardian Electric's booths at the IRE Show will be the new Guardian Series 2505 miniature d.c. relay featuring 6 pole, double throw contact combinations rated at 5 amperes. The unit is completely hermetically sealed in a standard metal enclosure less than 1-21/64" x 1-7/32" in size. Weight is .23 lbs. maximum. It has broad approval for military use; meets or exceeds specifications MIL-R-6106-C (Class B-8) including minimum current, and MIL-R-5757-C (Class A and B); also vibration requirements of 20 G's to 2000 cycles. All contacts are staked — not welded — for utmost reliability. Guardian's exclusive "fluxless solder" sealing is used to eliminate possibilities of internal contamination. Standard terminals are solder hook type. Plug-in terminals or potted leads also available.

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1960 INTERNATIONA IRE CONVENTION OPENS MARCH 21

New York's Coliseum and Waldo Astoria Hotel will be the site of wh has been termed "the World's Large Technical Event" when the 1960 Inte national IRE Convention commences c Monday, March 21st. Sixty thousa engineers are expected to be on hand f the 4-day meeting to see the introductio of over a thousand new product iten and hear first hand reports disclosin hundreds of major advances in all 2 branches of the radio-electronics field. I

There will also be a special symposiu on Tuesday evening, March 22, in whi the nation's leading experts will discu the future of space electronics.

Technical sessions will be held dai at both the Waldorf-Astoria and t Coliseum. Exhibits will be open fro 10 a.m. to 9 p.m. daily Monday th Thursday at the Coliseum. In additio a cocktail party will be held Mond evening, 5:30-7:30, in the Grand Ba room of the Waldorf-Astoria. The A nual IRE Banquet will be held on We nesday March 23, also in the Gra Ballroom of the Waldorf, at 6:45 p.

Members may register any day starti at 9 a.m. at either the Hotel or t Coliseum. A ladies program has be arranged for members' wives.

Following are excerpts from the tec nical program of special interest to m crowave engineers:

MONDAY AFTERNOON, MARCH

2. The Brookhaven Alternating-Gradie Synchrotron; Transistorized Nucle Instrumentation
Waldorf-Astoria, Astor Gallery

The Linear Accelerator Injector for t AGS, *S. D. Giordano, Brookhaven Na Lab., Upton, N.Y.*

Radio-Frequency Accelerating System f the AGS, *M. Plotkinfi Brookhaven Na Lab., Upton, N.Y.*

4. Radio Frequency Interference
Waldorf-Astoria, Sert Room

Simulation Tests on an Interference Reje tion Antenna System, *W. D. White a C. O. Ball, Airborne Instruments La Mineola, N.Y.*

Receiver Analysis for Interference Pred tion Purposes, *D. C. Ports, Jansky Bailey, Washington, D.C.; C. R. Mil and J. Savage, Rome Air Dev. Cent Griffiss AFB, N.Y.*

Electromagnetic Interference and Vuln ability Reduction, *J. J. Egli, U.S. Ar Signal R&D Labs., Ft. Monmouth, N*

6. Advances in Aerospace Subsystems
Coliseum, Faraday Hall

Range Ambiguity Resolution in High P Radar, *N. S. Potter, The W. L. Max Corp., New York, N.Y.*

An Ion Altimeter for Pressure-Altit Measurements, *G. V. Zito, Bendix A tion Corp., Teterboro, N.J.*

The Nature of Astro Doppler Velo Measurement, *J. E. Abate, Kearfott C Clifton, N.J.*

(*Continued on page 118*)

Extending existing modulation systems to make more space available in the spectrum, and possibly even broadening the useful spectrum . . . this is a fundamental problem in modern communications. It is the problem to which ITT Laboratories is devoting intensive effort.

At the low end we're designing a new type antenna for very low frequencies. With a conventional antenna this would require a tower more than three miles tall. On the top side — at the high end — we're making radiation pattern surveys for the super high frequency bands. Here the entire antenna consists of a few millimeters of number eighteen copper wire. We're matching these efforts with advances in componentry . . . for instance, the parametric amplifier and now the ingenious ferroelectric converter which converts solar heat to high voltage electricity to power new satellite communications.

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Flexural strength, psi	25,000
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Volume resistivity ohm/cm 25°C	6 x 10^{15}
Power factor 1 mc 20°C	.006
200°C	.14
Dielectric constant 1 mc 20°C	5.6
200°C	6.3
Loss factor	.034
Dissipation factor 1 mc 20°C	.0062

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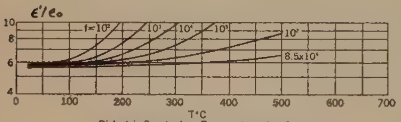
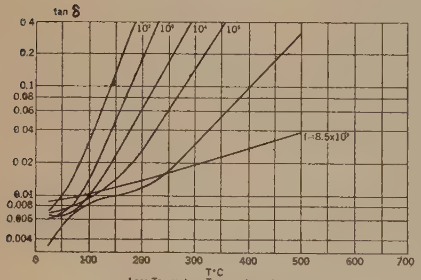


Dielectric Constant vs. Temperature at various frequencies between 100 cps & 8.5 kilo-megacycles



Loss Tangent vs. Temperature at various frequencies between 100 cps & 8.5 kilo-megacycles

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IRE Program

(Continued from page 116)

TUESDAY MORNING, MARCH 22

14. Varied Views of Medical Electronics
Coliseum, Faraday Hall

Biological Microwave Hazards, *V. T. Tomberg, Biophysical Res. Lab., New York, N.Y.*

15. Modern Approaches for Improved Air Traffic Management
Coliseum, Marconi Hall

An Air Height Surveillance Radar (AHSR-1), *T. J. Simpson, FAA, Washington, D.C.*

Automatic Ground-Air-Ground Communications for Control of Air Traffic, *W. R. Deal, FAA, Washington, D.C.*

Technical Research for Future Aviation Facilities, *N. Braverman, W. W. Felton, S. Justman, R. E. Kester, L. J. Schaub, and A. Wetter, FAA, c/o NAFEC, Atlantic City, N.J.*

A Mathematical Analysis of the Performance of the ATC Radar Beacon System, *A. Ashley and F. H. Battle, Jr., Airborne Instruments Lab., Mineola, N.Y.*

16. Broadening Device Horizons
Coliseum, Morse Hall

Masers, *J. W. Meyer, MIT, Lincoln Lab., Lexington, Mass.*

Variable Reactance Devices, *B. Salzberg, Airborne Instruments Lab., Mineola, N.Y.*

Tunnel Diodes, *H. S. Sommers, Jr., RCA, Princeton, N.J.*

Functional Devices, *W. A. Adcock, Texa Instruments, Dallas, Tex.*

TUESDAY AFTERNOON, MARCH 22

17. Radar and Coding Theory
Waldorf-Astoria, Starlight Roof

Sequential Procedures in Radar Pretracking, *M. Schwartz, Polytechnic Ins Brooklyn, Brooklyn, N.Y.*

Detection Range Predictions for Puls Doppler Radar, *S. A. Meltzer and S Thaler, Hughes Aircraft Co., Culve City, Cailf.*

The Search Efficiency of the Sequentia Probability Ratio Search Radar, *G. W Preston, General Atronics Corp., Bala Cynwyd, Pa.*

23. Microwave Tubes
Coliseum, Morse Hall

High-Power CW X-Band Amplitron, *W Brown, Raytheon Co., Waltham, Mass.*

High-Power L-Band CW Traveling-Wav Tube Amplifiers, *R. Strauss and J. McCammon, Sperry Electronic Tube Div. Gainesville, Fla.*

The Effects of Magnetic Focusing Fiel and Transverse Beam Velocities on Spu ious Oscillations in Backward-Wave Oscillators, *L. L. Maninger, Sylvania Elec Products, Inc., Mountain View, Calif.*

The Design and Performance of a Commercial Ammonia Maser Oscillator, *S. Hopfer, Polytechnic Res. & Dev. Co., Brooklyn, N.Y.*

Extended-Dynamics-Range Traveling-Wav Tubes, *J. Kliger and E. J. Downe Hughes Aircraft Co., Culver City, Cali*

(Continued on page 120)

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IRE Program

(*Continued from page 118*)

TUESDAY EVENING, MARCH 22

24. Electronics — Out of This World

Waldorf-Astoria, Grand Ballroom

Inter-Galactic Data, *L. V. Berkner, Associated Universities, New York, N.Y., and M. Tepper, NASA, Washington, D.C.*

Weather Forecasting and Control, *L. de Florez, USNR, Englewood Cliffs, N.J.*

Reconnaissance — Radio, Radiation, Infrared, Optical, *B. S. Pulling, Deputy for Radiation Warfare Support, WPAFB, Ohio.*

Design for Survival (Personnel and Material), *H. Strughold, School of Aviation Medicine, USAF, Randolph AFB, Tex.*

Communication Relaying, *J. B. Wiesner, MIT, Cambridge, Mass.*

WEDNESDAY MORNING, MARCH 23

25. Detection Theory and Applications to Physics

Waldorf-Astoria, Starlight Roof

Estimation of Doppler Shifts in Noise Spectra, *P. Swerling, The Rand Corp., Santa Monica, Calif.*

Optimum Coincidence Procedures for Detecting Weak Signals in Noise, *J. Capon, Federal Scientific Corp., New York, N.Y.*

A General Theory of Signal-to-Noise Ratio Improvement, with Application to the Visual Detection of Weak Signals, *N. S. Potter, The W. L. Maxson Corp., New York, N.Y.*

Information Rates in Photon Channels and Photon Amplifiers, *T. E. Stern, Columbia Univ., New York, N.Y.*

An Aspect of Information Theory in Optics, *H. Gamo, IBM Res. Center, Yorktown Heights, N.Y.*

28. Space Telemetry

Waldorf-Astoria, Sert Room

Evaluation of Modulation Methods for Telemetry Usage, *M. Rudin and D. Childers, Aeronutronic Div., Ford Motor Co., Newport Beach, Calif.*

Conceptual Design of a General Purpose Telemetry System, *W. F. Link, Aeronutronic Div., Ford Motor Co., Newport Beach, Calif.*

Detection Levels and Error Rates in PCM Telemetry Systems, *A. V. Balakrishnan and I. J. Abrams, Space Technology Labs., Los Angeles, Calif.*

A Highly Precise FM/FM Telemetering Device, *H. K. Schoenwetter, Hoover Electronics Co., Timonium, Md.*

30. Communication Systems Design

Coliseum, Faraday Hall

Equipment Configuration and Performance Criteria for Fully Optimized Tropospheric-Scatter Systems, *C. A. Parry, Page Communications Engineers, Washington, D.C.*

Multifold Diversity Combining Techniques, *R. T. Adams, ITT Labs., Nutley, N.J.*

Simple Methods for Designing Troposcatter Circuits, *L. P. Yeh, Page Communications Engineers, Washington, D.C.*

Optimized SSB Transmitter Loading by Multichannel Frequency Division Data, *A. T. Brennan and J. P. Daly, Stromberg Carlson, Rochester, N.Y.; and B. Goldberg, U.S. Army Signal R&D Labs., F Monmouth, N.J.*

"Quicksilver" — A Long-Range Genera Purpose Digital Communications Sy tem, *A. C. Chapman, Hughes Aircra Co., Los Angeles, Calif.*

32. Microwave Filters

Coliseum, Morse Hall

Band-Pass Microwave Filter Design — New Method and Its Relation to Oth Methods, *G. L. Matthaei, Stanford Re Inst., Menlo Park, Calif.*

Optimum Quarter-Wave Transformers, *Young, Westinghouse Elec. Corp., Bal more, Md.*

Magnetically Tunable Microwave Filte Employing Single-Crystal Garnet Rese nators, *P. S. Carter, Jr., Stanford Re Inst., Menlo Park, Calif.*

Harmonic Calorimeter for Power Measur ments in a Multimode Waveguide, *V. Price, GE Microwave Lab., Palo Alt Calif.*

WEDNESDAY AFTERNOON, MARCH 23

37. Communication System Techniqu

Coliseum, Faraday Hall

Analysis of a Phase Modulation Commu cations System, *R. L. Choate, Californ Inst. Tech., Pasadena, Calif.*

An Improved Decision Technique for Fr quency Shift Communications System *E. Thomas, Page Communications Eng neers, Washington, D.C.*

High Sensitive Receiving Systems for Fr quency Modulated Wave, *M. Morita a S. Ito, Nippon Elec. Co., Kanagawa-k Japan.*

Men who know* prefe

Improved Multiplex Voice Frequency arrier System, *B. Tennent, Philips lectronics Industries, Ltd., Toronto, anada.*

Antenna Pattern Synthesis
Coliseum, Marconi Hall

el Members: *R. C. Spencer, The Martin o., Baltimore, Md.; P. A. Bricout, Liton Industries, College Park, Md.; and . Bickmore, Hughes Aircraft Co., Culer City, Calif.*

ivative Control in Shaping Antenna atterns, *A. Ksienski, Hughes Aircraft o., Culver City, Calif.*

e New Methods of Analysis and Synhesis of Near-Zone Fields, *M. K. Hu, yracuse Univ., Syracuse, N.Y.*

thesis of $CSC^2\theta$-Type Antenna Patterns sing Two-Dimensional Surface Wave rrays, *H. W. Cooper and H. R. Mcomas, Westinghouse Air Arm Div., altimore, Md.*

ermination of Optimum Primary Feed llipticity Setting to Obtain Circular olarization from Reflector-Type Annnas, *L. J. Kuskowski, Airborne Inruments Lab., Melville, N.Y., and A. . McCoy, Raytheon Co., Wayland, lass.*

Microwave Interaction with Matter
Coliseum, Morse Hall

el Members: *S. C. Brown, MIT, Camridge, Mass.; C. L. Hogan, Motorola, nc., Phoenix, Ariz.; and H. Kroemer, arian Associates, Palo Alto, Calif.*

ent Progress in Microwave Beam, lasma and Solid-State Devices, *L. M. Field, Hughes Aircraft Co., Culver City, Calif.*

Microwave Interaction with Plasmas, *R. G. Buser and P. Wolfert, U.S. Army Signal R&D Labs., Ft. Monmouth, N.J.*

A New Semiconductor Microwave Modulator, *H. Jacobs, F. A. Brand, and M. Benanti, U.S. Army Signal R&D Labs,. Ft. Monmouth, N.J.; and R. Benjamin, Monmouth College, West Long Branch, N.J.*

THURSDAY MORNING, MARCH 24

41. Circuit Theory: Current Contributions
Waldorf-Astoria, Astor Gallery

Broad-Band UHF Distributed Amplifiers Using Band-Pass Filter Techniques, *F. C. Thompson, HRB-Singer, Inc., State College, Pa.*

43. Equipment and Systems
Waldorf-Astoria, Sert Room

Missile Master (AN/FSG-1) — System Functional Description, *G. Romano, D. L. Prentice, and J. Hayne, The Martin Co., Orlando, Fla.*

Missile Master (AN/FSG-1) — System Equipment Description, *R. Staschke and D. Noden, The Martin Co., Orlando, Fla.*

Weather Radar Data Processing, *O. Lowenschuss, Budd Lewyt Electronics, Long Island City, N.Y.*

A Building-Block Approach to Multipurpose Communication Equipment, *L. G. Fobes and J. E. Martin, U.S. Army Signal R&D Labs., Ft. Monmouth, N.J.; and H. A. French, W. L. Glomb, and M. W. Green, ITT Labs., Nutley, N.J*

An Integrated Approach to the Design of Mobile Tactical Electronic Systems, *R. N. Skalwold and M. N. Scheiderich, Rome, N.Y.*

Electronic Equipment Weight and Volume Penalties to Flight Vehicles, *W. V. White, Collins Radio Co., Cedar Rapids, Iowa.*

44. Satellite Communications
Waldorf-Astoria, Empire Room

Radio Relaying by Reflection from the Sun, *D. J. Blattner, RCA Labs., Princeton, N.J.*

Active vs Passive Satellites for a Multistation Communication Network, *L. Pollack and D. Campbell, ITT Labs., Nutley, N.J.*

Satellite Communication Problems and Solutions in Ground Station Design, *W. L. Glomb, ITT Labs., Nutley, N.J., and W. Teetsel, U.S. Army Signal R&D Labs., Ft. Monmouth, N.J.*

Detail Design of an Operational Missile Voice Frequency Communications System, *W. S. Cayot, Nortronics, Hawthorne, Calif.*

A Digital Data Handling System for Real-Time Computation on the Atlantic Missile Range, *M. P. Falls, RCA Service Co., Patrick AFB, Fla., and T. A. Christie, Jr., Stanford Univ., Stanford, Calif.*

46. Scanning Antenna Arrays
Coliseum, Marconi Hall

Panel Members: *J. Ruze, Radiation Engineering Lab., Maynard, Mass.; H. Shnitkin, The W. L. Maxson Corp., New*

(*Continued on page 124*)

You join the ranks of those who know* when you specify McMillan absorbers for *your* "free space" rooms. The list of McMillan customers is a veritable "who's who" in the electronics industry and includes such leaders as — Avco, Bell Labs, Bendix, Cambridge Research Center, Convair, General Electric, Johns Hopkins, MIT Lincoln Labs, Philco, Westinghouse and many others.

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RECORD ATTENDANCE AT 1960 SOLID-STATE CIRCUITS CONFERENCE

Over 3000 attended the recent 1960 International Solid-State rcuits Conference which was held on the campus of the iversity of Pennsylvania and the Sheraton Hotel in Phila- phia.

Among those in attendance were scores of solid-state special- from abroad — Japan, Italy, France, Sweden, Hungary, itzerland, England and the Netherlands.

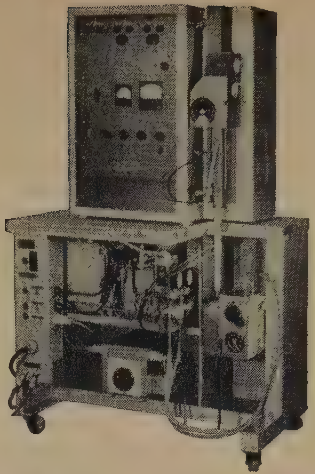
Honored guests included Leo Esaki of tunnel-diode fame; J. O. Strutt, chairman, Electrical Engineering Department, ss Federal Institute of Technology and C. Guy Suits, Vice- sident and Director of Research, General Electric Company, latter two delivering invited addresses at the formal opening the meeting.

formal opening of the Conference are, left to right: Arthur Stern, Chairman of Conference; C. Guy Suits, Vice-President, ector of Research, General Electric and M. J. O. Strutt, airman, Electrical Engineering Department, Swiss Federal titute of Technology, both of whom delivered invited ad- sses; and G. P. Harnwell, President, University of Penn.

moving tribute was paid to the late Dudley Buck during afternoon memorial session.

complete conference report — 100-page-letterpress-book h over 300 illustrations — covering the 43 papers presented, distributed to all registrants. Post-conference copies of text, officially known as the *Digest of Technical Papers,* are lable from: Henry G. Sparks, Moore School of Electrical ineering, University of Pennsylvania, Philadelphia 4, Pa., at 0 per copy. Remittance to be made out to: "Solid-State uits Conference."

rflow attendance at informal discussion on tunnel-diodes at the Sheraton Hotel.



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Multidirectional Antenna — A New Approach to Stacked Beams, *J. Blass, The W. L. Maxson Corp., New York, N.Y.*

Parasitic Spiral Arrays, *R. M. Brown, Jr. and R. C. Dodson, U.S. Naval Res. Labs., Washington, D.C.*

An Electromechanically Scannable Trough Waveguide Array, *W. Rotman, AF Cambridge Res. Center, Bedford, Mass., and A. Maestri, Melpar, Inc., Falls Church, Va.*

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MARCH 24

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A Pulsed Plasma Mechanism for Propulsion in Space, *P. M. Mostov, J. L. Neuringer, and D. S. Rigney, Republic Aviation Corp., Farmingdale, N.Y.*

Design Considerations of Television Satellite Reconnaissance Systems, *R. L. Zastrow and D. J. Ritchie, Bendix Aviation Corp., Detroit, Mich.*

Scanning Methods for Satellite-Borne Radars, *A. Rosenfeld and O. Lowenschuss Budd Lewyt Electronics, Long Islan City, N.Y.*

A Study of Natural Electromagnetic Phenomena for Space Navigation, *R. G Franklin and D. L. Birx, The Frankli Inst., Philadelphia, Pa.*

51. Check-Out Instrumentation and Circuitry
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A Monopulse Cassegrainian Antenna, *L Schwartzman and R. W. Martin, Sperr Gyroscope Co., Great Neck, N.Y.*

Power-Handling Capability of Antennas a High Altitude, *W. E. Scharfman an T. Morita, Stanford Res. Inst., Menl Park, Calif.*

Propagation Measurements in Shock-Ionized Media, *D. E. Sukhia and G. H Hampton, The Martin Co., Baltimor Md.*

Ultra-Low Frequency Atmospherics, *H Konig, Electro-Physical Inst., College o Technology, Munich, Germany.*

Ray Tracing for Whistler-Mode Signals Low Frequencies, *E. R. Schmerlin Pennsylvania State Univ., State Colle Pa.; R. Goerss and S. Miluschewa, RCA Hightstown, N.J.; and P. Hertzler an I. Pikus, RCA, Camden, N.J.*

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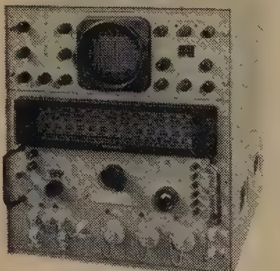

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— *mwj* —

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unit of the Microwave and Power Division, Special Microwave De- Operations is managed by Dr. ard Scharfman of Lexington, Mass.

rmed in 1956, the operations pio- d in development of miniature ro- nal isolators, reciprocal switches, d-band modulators, high power iso- s and circulators for UHF, L, and ds. In addition, the group developed ture circulators for 400 to 17,000 cycle maser and parametric ampli- pplications.

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cture Series (*Cont'd from p. 61*)

TURE V FERRITES AND SOLID STATE DEVICES

F. Arams and S. Okwit
Airborne Instruments Laboratory
Melville, L.I., New York
30 - 9:30 p.m. April 26, 1960

he first half of this lecture will be oted to the consideration of ferrite ces in waveguide, coaxial lines, and lines. Applications and perform- characteristics of state of the art ponents will be covered. Power con- rations and frequency limitations will mong the areas of performance to be ussed.

he last half of this lecture will em- e the solid state field as related to owaves. The latest available infor- on on masers and parametric ampli- will be covered. Also included will he possible microwave application of nel diodes and related devices.

TURE VI ANTENNAS AND PROPAGATION

Dr. J. Blass
L. Maxson Corp., New York, N.Y.
30 - 9:30 p.m. May 3, 1960

his lecture will discuss various an- a types: such as, reflectors, arrays, uency scanners, and lenses. Theo- al limitations in practical antennas be covered. This will include, in tion to propagation problems, beam- th, bandwidth, side lobes, absolute , aperture, noise considerations, and sical limitations.

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STARTING A NEW MICROWAVE BUSINESS

GERSHON J. WHEELER
SYLVANIA ELECTRIC PRODUCTS, INC.
Mountain View California
Associate
the microwave journal

AT ONE TIME OR ANOTHER everyone dreams of ning his own company and being responsible to no one himself. In this respect, microwave engineers are cerlly no exception. In fact, if in a group of engineers one uld casually mention that he is considering starting a business, it is amazing (and flattering) to find so ny willing to join in the enterprise. This is puzzling. hey are so eager, why do they wait for someone else start the ball rolling instead of doing it themselves? at special attributes or talents are necessary in those actually start a new business? In microwave businesses particular, why do engineers band together in groups, en frequently there is one talented individual in the up who is capable of going it alone and reaping all benefits?

o learn the answers to these and other questions, I ided to interview the heads of five young microwave npanies. (No, I am not considering starting a new npany, myself). They were not picked at random, but e chosen because they represented five different backunds. The list follows:

ack Melchor of MELabs (formerly Microwave Engineering Lab)
tan Kaisel of Microwave Electronics
ohn Granger of Granger Associates
ean Watkins of Watkins-Johnson
ill Ayer and Pete Strum of Applied Technology

were extremely cooperative and made many helpful gestions.

he group that formed MELabs left a large company. y have concentrated their efforts in advanced developnt in special fields, including solid state and reconsance. Consequently, they rely almost entirely on F contracts. The company, formed in the spring of 6, now has 153 employees. (December, 1959).

he group that formed Microwave Electronics also left rge company. In contrast to MELabs, however, they developing and producing a proprietary line of TWT's do no CPFF work. They now have twenty employees, r about six months of operation.

he two founders of Applied Technology left a small npany. They are doing advanced development of speelectronic systems. This company has nine employees is the youngest of the five.

ohn Granger directed the activities of approximately employees at Stanford Research Institute. His comy works on special antennas and systems, including onnaissance and ECM. After three years of operation, company has 84 employees.

Dean Watkins is a professor in the Electrical Engineering Department at Stanford. He still holds this academic position while he lends his talents to Watkins-Johnson, which is engaged in the development of special tubes, including the Helitron and TWT's. The company was formed in August, 1958 and now has 65 employees.

Before considering the reasons why one might start a new business, it might be well to consider the deterrents to doing so. Jack Melchor listed three: the desire for security, lack of self-confidence, and advanced age. The last is probably tied to the first, since an older man would find it more difficult to find a new job if his venture failed. The inference here is that self-confidence is a necessary ingredient, and, in fact, each of the people interviewed mentioned self-confidence as being of prime importance. Each one felt confident in his own abilities to be successful in this new venture. But even if he might fail, he would not fear insecurity, because he had confidence in his own technical ability which would enable him to get a new job.

But were they really that confident? When asked why they banded together in groups of two or more to form the company, some admitted that perhaps there was a tiny seed of doubt and the willingness of others to take the same risks bolstered their self-confidence. Others pooh-poohed this idea, explaining the groups on the basis that in a complex business, complex skills are needed, and no one individual has all these skills.

It is interesting to note that the two groups which left large companies deplored the slowness in making decisions and red tape necessary in a large company. The others, too, were in accord on this point and frequently mentioned the flexibility and other advantages of a small company. Yet all realize that in an expanding economy such as ours it is necessary to grow in order to stand still and all are "resigned" to becoming medium-sized companies and eventually large companies.

Dissatisfaction with working conditions apparently is not a reason for starting a new company. Obviously, if an engineer is unhappy with the slowness and red tape in a large company, he can surely find work in a small company. Likewise, if the too close scrutiny of a small firm bothers him, there are plenty of opportunities in larger organizations. Dissatisfaction, then, may start an engineer looking for a new job, but by itself it won't start him thinking about owning his own business.

Interestingly enough, inadequate salary, although often mentioned as a reason for changing jobs, is nevertheless almost never the real reason. Other sources of annoyance and dissatisfaction, some minor by themselves, have already

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